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CHEMICAL SECTION.

PHOTOGRAPHIC AND MICROSCOPIC BRANCH.

THE MAKING OF PHOTOGRAPHY.

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[An Address delivered in Convention Hall, National Export Exposition, Monday, October 2d, on the Occasion of the Celebration of the Seventy-fifth Anniversary of the Franklin Institute.]

Standing at the close of three-quarters of a century, marked by intense scientific activity attended by amazing progress along all lines, the most superficial consideration of photography and its applications exhibits it as one of the most important factors in the life of to-day, evolved from that activity. Using the term in its most comprehensive conventional sense, it touches at numberless points all sciences, all professions, all trades and industries. It would be a hopeless task to compress into the limited time, very properly assigned to this the most recent branch of this

Section, on this occasion the most imperfect statement of the achievements of photography, to say nothing of indulgence in speculations as to its further possibilities. But the occasion does not seem to require it. It belongs to the Franklin Institute, and at this, its seventy-fifth anniversary, it seems appropriate to consider photography and its history in its relations to the Institute, for photography and the Franklin Institute were young together. They have grown up together. It has had a share in the making of modern photography. When the Franklin Institute was founded, the word photography had not been coined, or at least had not struck the ear of the lexicographer. It may have been one of many words used according to the fancy of the individual investigator to connect the accumulating facts of an inchoate branch of science; but it was not the first, and when it did put in an appearance, it was not free from adverse criticism. There was a time when heliography may have been preferable, but with the extended industrial use of the electric light, magnesium light and even gas light, to say nothing of the Röntgen rays, it would be much more of a misnomer to-day than photography, which word must be regarded as holding its place to-day, as the survival of the fittest. It is an interesting coincidence, too, that the year that witnessed the founding of the Franklin Institute is, perhaps, the most important in the history of photography. It was not, it is true, the year in which any important discovery was made or announced. It was simply the initial year of those experiments that culminated in the discovery that constitutes the birth of modern photography. It was in that year that Daguerre first turned his attention to photographic investigations. For after all has been allowed that is to be credited to, or even claimed for others, he still remains the central figure in photographic history. Photographic events date backward and forward from him. Without his discovery all photographic that preceded him would have been embalmed in the history of science, overlooked and perhaps entirely lost, until revived by the touch of some such great discovery as his. His success at once caused all records to be ransacked, to be assured that he had, indeed, made so unique and mar-

vellous a discovery. As usual in such cases, some things were found that at first sight seemed to reduce his claims, but which, when fully considered, do not affect them in the least. In 1824, then, he entered upon the fourteen years of solitary, discouraging, almost hopeless, but unintermitted experiments, that finally resulted in the discovery to which his name has adhered. Accustomed as we have become to the almost daily announcement of similar great unexpected and unheralded discoveries, we can hardly realize the sensation it created, nor the struggle between the great desire to believe it true, and the incredulity of that day, so much greater than that of our own. This was even heightened about that time by the then recent "Moon hoax," to which the announcement of Daguerre's discovery was compared, even by scientific men. In his classical history of chemistry, Kopp, who doubtless wrote from personal acquaintance with individuals present in Paris at the time, in seeking for a parallel to the excitement occasioned by Davy's great discovery of the metals of the alkalies, in the early part of the century, says of it, "something like that occasioned by Daguerre's discovery in our time." From that date, 1839, we pass rapidly backward into the hazy prehistoric period, that belongs to every branch of science, from which many interesting items have been recovered by the curiosity aroused by the practical success of his process. From that date forward, we have only to note an immediate, rapid, steady development. There is no disposition by this statement to unduly magnify the merits of Daguerre, much less to minify the claims of others, but simply to accentuate the epoch-making character of his discovery. So much has been written with a bias, in many cases inspired by national partiality, and is being so frequently repeated, that the salient and indisputable facts are often overlooked. It may not, therefore, be out of place here to bring together rapidly facts generally received, in such connection and sequence as to exhibit the origin and making of modern photography.

What then was the condition of photographic research in 1824? Overlooking all alchemistic and other accounts, however curious and interesting, but without effect upon

the history of photography, we find, in 1777, the illustrious Swedish chemist, Scheele, engaged in investigating scientifically, carefully, we might almost say exhaustively, the interesting fact, long known, that silver chloride darkens under the influence of light. He allowed sunlight that had passed through a prism to fall upon silver chloride spread upon paper on the floor of the darkened room, and demonstrated that the violet ray was most effective in producing the change. He further established the fact that chlorine was liberated in the operation. But this, the usual, statement of these facts, and a correct one from the point of view of to-day, conveys a very wrong impression of Scheele's purpose, and of his interpretation of his results. The object of his investigation was not the action of light on silver chloride, but the action of silver chloride, or horn silver, as it was then called, on light; and he did not state his results in the way given. The scientific world of that day was dominated by the curious, almost fanciful, phlogiston theory of combustion. That hypothetical something, or nothing, was always present in their thoughts whilst investigating. Scheele was trying to demonstrate that phlogiston was present in sunlight, and he explained his results by saying that silver calx removed the phlogiston most rapidly from the violet ray. The change in the silver chloride he explained as loss of dephlogisticated spirit of salt. Disentangled then from the theories of his day, Scheele made two important discoveries, which we recognize to-day as photographic. Many eminent investigators repeated his experiments. In 1798 Rumford, as the result of elaborate experiments, contended that the change was due to heat, and not to light. In 1801 Ritter, incited doubtless by the detection of heating effect, by Sir W. Herschel, the year before, in the space beyond the red of the spectrum, announced the discovery of photographic effect in the invisible region beyond the violet. He also demonstrated an opposition of effect of the red and violet rays, and explained it by an oxidizing action of the former, and a reducing action of the latter. In 1802 Wollaston arrived at substantially the same results; but in investigating Ritter's explanation of the opposition of the red and violet rays, from which he dis-

sented, he employed a photographic substance of a new class, namely, gum guaiacum, and considered its change of color under the influence of light. In 1804 Young employed a silver salt successfully to investigate Newton's rings, projected by a solar microscope. So Vogel, Seebeck, Senebier, Davy, Berard, in fact almost every scientific man of prominence of that period, pursued similar lines of investigation. The motive of most of these was strictly scientific, such as the determination whether the solar beam contained three essentially different agents, of which the actinic was but one, the photogenic production of the colors of the spectrum, the exploration of the invisible regions of the spectrum, and the like. In the apparent chaos of carefully observed facts, there are many that advanced photography of to-day imparts new interest to, and that might well repay reinvestigation. There was but one notable attempt at practical application of facts. In 1802 Thomas Wedgewood, son of the porcelain manufacturer, in connection with Davy, published a method of copying pictures painted on glass, fibers of leaves, wings of insects, and so forth, by pressing them in contact with paper coated with nitrate or chloride of silver and exposing to sunlight; but, failing in all their efforts to prevent the continued darkening of the pictures obtained in this way by the action of light, they were obliged to preserve them in the dark, and could only examine them by candlelight.

During the decade preceding the founding of the Institute there was almost a complete lull in scientific activity along these lines. During this time, however, there was one man, Nicephore Niépce, who had been working on from 1814, with great tenacity of purpose, trying to fix the images of the camera. He had sufficient suggestions of success to keep him at work. He did not approach the subject from the scientific side, nor from purely scientific impulses, but with a desire for immediate practical results. He had become interested in the recently-discovered process of lithography. The difficulty of procuring suitable stone suggested the use of metallic plates, and it occurred to him to substitute light for the hand in drawing the pictures. After experimenting with various substances, among them

silver chloride, he discovered that bitumen of Judea was rendered insoluble in certain solvents by the action of light. He coated metallic plates with a thin varnish of it; exposed them when dry to the sunlight under engravings, previously varnished to render them more transparent, and then dissolved out the unchanged bitumen of the parts protected from the light. After a measure of success in thus copying engravings, he experimented with the pictures of the camera on similar plates, and there seems to be no question that about 1827 he had obtained pictures by this process, however imperfect. He named the process "Heliography."

In 1824, Daguerre, entirely ignorant of Niépce or his work, entered upon a similar pursuit, upon parallel lines, inspired by a similar desire for immediate practical results. He was a scene painter in Paris, and an artist of no mean character, and of great popularity in that city. The diorama, invented by him, was the sensation of the day. Crowds were entertained by its surprising effects. He was aided by the camera in preparing his scenes. The wish to fix its fleeting pictures might occur to any one, but it took complete possession of him, although the pursuit was more unpromising than that of the alchemists. He worked alone and in secrecy, with but little encouragement. His methods were empirical rather than scientific. About 1826 he learned of another worker in the same field. He immediately wrote to him. Niépce, distrustful of the unknown writer, threw the letter in the fire. A letter a year later met with a better reception. The correspondence continued, at first with almost suspicious reserve. Niépce visited Paris, met Daguerre, was greatly impressed with his diorama. Both seemed to enjoy an exchange of experiences that belonged to them alone. Niépce wrote his son, that Daguerre persisted in regarding his (Niépce's) process as better than his own, but that one thing was certain, they were entirely different. A partnership, styled Niépce-Daguerre, was formed, with equal interest. The article of agreement, dated December 14, 1829, was signed by Niépce as "Land owner at Chalons sur-Saone," and by Daguerre as "Artist Painter, Member of the Legion of Honor, Manager

of the Diorama." Under the terms of the partnership, Niépce contributed his process of Heliographie, and his experiments, which Daguerre agreed to assist in improving, and also contributed his improved camera, which was regarded as of great value, as it most likely was. Daguerre improved the process, but was diverted altogether from it by the accidental discovery of the sensitiveness of silver iodide to light. In the bitumen pictures the blacks of the original were represented by bright polished metal, from which the unchanged bitumen had been removed, and the whites by the changed bitumen. To convert these negative pictures into positives, Niépce experimented with a variety of substances, among them vapor of iodine, to darken the exposed metal, and then dissolved off the bitumen from the whole plate. It is said that Daguerre observed, that the shadow of a spoon that happened to be lying on a polished silver plate that had been exposed to the vapor of iodine, was permanently impressed upon it. Slight as every one knows this direct effect of light on iodide of silver to be, Daguerre seemed to see in it new possibilities for camera pictures. Niépce, however, after experimenting with it at Daguerre's suggestion, expressed regret that he had lost so much time in following his recommendation. He repeated that he did not see that they could hope to secure any advantage from this process, and suggested other substances as better. Niépce died in 1833. Success seemed as remote as at the formation of the partnership. The partnership was renewed with the son, Isidore Niépce. Daguerre now entered with even greater enthusiasm and undivided effort into the pursuit. He neglected the diorama, and lived in his laboratory, to which no one had access, not even Isidore Niépce. He became so much wrought up by his unsuccessful experiments that his wife, according to Dumas, consulted physicians in regard to his sanity. Finally there came to his assistance an accident which conducted to a fundamental discovery, as fundamental to-day as it was then. The mode of the discovery has not only a species of romantic interest of its own, but, as I recollect it, given by Professor Liebig in one of his lectures, as one of the finest specimens of the

inductive method, coming thus from one thoroughly familiar with the Paris of that day, it has an added air of authenticity that may excuse the narration of it in this connection. Daguerre's method of experimenting was to expose polished silver plates to the vapor of iodine until coated with a layer of iodide, then to subject them to the image in the camera. These plates, always without the hoped-for result, or at most the very feeble direct effect, were repolished, reiodized, re-exposed in the camera with the same disheartening results. On one occasion, upon removal of such an exposed plate from a closet, in which it had been stowed, to repolish it for a new experiment, to his great surprise he found upon it the view to which it had been exposed in the camera, not an uncertain, feeble picture, such as he had been accustomed to, but a strong, clear, unmistakable one. He exposed another plate in the camera, without visible effect, stowed it in the closet, again to find the invisible picture put in an appearance. He had no way of explaining the result. All his years of investigation furnished him no clue to the influence at work. He set about systematically to discover it. He could only conclude that it must be something in the closet. He placed plate after plate, after exposure in the camera, in the closet, each time first removing something from the closet. Each time the invisible became visible. At last nothing remained but some mercury spilled on the floor of the closet. Thus by this method of elimination the magician was detected. It was a short step to subject plates that had been exposed in the camera to vapor of mercury, and the daguerreotype process was complete. But the discovery was far more than simply that of a process. It was that light can produce an invisible effect, a latent effect, as it has been called, previously entirely unsuspected, which may be rendered visible by suitable agents, which we call developers, and, what was of most practical value, an effect produced in so short a time as to render camera pictures easily possible. Upon it all modern photography, the prime factor in which is the negative, is based, and a great part of the photographic literature of to-day deals with development and developers. If one name, then, is to be selected

as representative in the history of photography, there can be no question but that it should be that of Daguerre. This seems to have been the view taken by the authorities of the Congressional Library at Washington, and there was a singular fitness in placing his name there with that of Guttenberg in the Hall of Inventors. The name of Niépce might have been placed there too, but certainly in a subordinate position, or have been left out, as it has been, without manifest injustice, although his merit is of a high order. He was an independent, ingenious, indefatigable experimenter and investigator. His bitumen process may be regarded as entirely his own, although the important principle underlying it, of change of solubility effected by light, today of widely-extended application, was, at least, suggested to him, according to a letter by him, by the experiments of Wollaston with gum guaiacum, which experiments, however, his own failed to substantiate. Although his process was measurably successful, it was extremely slow as a camera process, requiring from six to eight hours in the sunlight, and not only imperfect, but impracticable, and, looked at even from our present point of view, had in it no possibility of growth or development into a practicable camera process. There is nothing in it in common with, or suggesting in any degree, the negative processes of to-day, and, however creditable his work and its results, photography, as we understand it, would have begun and ended with Niépce and his process. The discovery of Daguerre, however, of a latent effect of light, produced in a much shorter time than any direct effect and developable, was a unique fact in science. It was independent of, and unsuggested by, anything that had preceded it. The guesses of Sir John Herschel in regard to it, after its announcement and before its publication, accentuate this important fact. It was in the line of his investigations, and in commenting on Daguerre's concealed process, as he termed it, he gave four possible explanations of it, no one of which proved to have anything in the remotest degree in common with it, as published a few months later. It had in it all the possibilities of the negative processes of to-day, in which time of

exposure has been reduced to the smallest fraction of a second, as shown in the kinetoscope and the snap shots of the amateur. The development of modern photography, with all its practical applications, from it was like the growth, and very rapid growth, from a germ.

Had this fact been left by Daguerre with simply the suggestion of a practical application, its importance would have been the same. But he gave a process founded upon it commercially complete, immediately available, with results possessed of highest intrinsic merit, which contributed much to the growth of practical photography. An account from a Parisian newspaper of the day will serve to emphasize this statement as to the character of the results: "The deputies" (of the French Assembly) "during the day crowded to the room attached to the Chamber of Deputies, in which the pictures were displayed." "They were struck with the marvellous minuteness of detail which these views, especially those of the streets, exhibited." "In the one of the Pont Marie all the minutest indentations and divisions of the ground, or the buildings, the goods lying on the wharf, even the small stones under the water at the edge of the stream, and the different degrees of transparency given to the water, were all shown with the most incredible accuracy. The use of a magnifying glass revealed an infinity of other details quite undistinguishable by the naked eye, etc." This might be taken as the description of a first-class photograph of to-day. But it may be said, after all, it was only the result of a happy accident. That could be said of many discoveries. The list of such accidents to purely scientific men would be a long one. But such accidents only happen to such men as work their way across their paths, and can appreciate them, otherwise they come and go unnoticed. The accident is frequently the final event of a long series that seems to be credited with too large a share of the ultimate success. Daguerre was a lucky fellow, but he was not a scientific Micawber. The commercial reception of the discovery is interesting, perhaps instructive. In 1838 the process was considered so far advanced as to be put in operation. From March 15th to April 15th subscription books

were kept open for 400 shares of 1,000 francs each. Not a share was taken. The process was offered for 200,000 francs and no purchaser appeared. In January, 1839, the secret was imparted to Arago, who was so impressed by it that he exerted himself to procure recognition for it from the French Government, which pensioned Daguerre and Niépce, and gave the discovery as a gift to the world, without the restriction of a patent, except in England, where one had already been taken out. On the 10th of August, 1839, the process was communicated by Arago to a joint meeting of the Academy of Sciences and the Academy of the Fine Arts, held for the purpose. The Mazarin Palace in which the meeting was held was not only filled with an audience of unusual character, but the approaches to it were crowded.

This early period of photography cannot be passed over without mention of the name of Henry Fox Talbot, of England. He was a man of many-sided scientific character, and an independent investigator in the photographic field prior to Daguerre's discovery, and therefore not inspired by it to investigation. In 1839, January 31st, he read a paper before the Royal Society, entitled, "Some Account of the Art of Photogenic Drawing, etc.," embodying a practical process on paper based on the abandoned process of Wedgewood and Davy, which he improved and also completed by fixing the pictures, although imperfectly, in a solution of common salt or potassium iodide. The substitution of sodium hyposulphite, first suggested by Sir John Herschel, for the iodide soon followed. He further suggested indefinite photographic multiplication of the paper originals, by taking impressions from them on similarly prepared paper, and upon the publication of Daguerre's discovery of a latent effect of light, was quick to apply it to the preparation of a paper sensitive enough for camera impressions; and by rendering these transparent, greatly facilitated indefinite photographic multiplication of the original negatives as positive pictures, although the terms negative and positive, in this connection, were first used by Herschel. His Calotype process was patented by him in 1841. Although there is nothing in it that would call for

the association of his name with those of Daguerre and Niépce, yet, as an independent investigator, scientifically trained, he deserves prominent mention, as one whose application of known facts at once greatly stimulated the practice of photography and its consequent rapid improvement. In addition to the introduction of photographic multiplication by the use of a translucent support for the sensitive compound of silver, the replacement by him of the formation of such a compound by the direct combination of the halogen with the silver, as in Daguerre's process, by the reaction between silver nitrate and a metallic haloid, was typical of more modern photography.

It is interesting at this point to note the reception of the discovery in America. There was at least one man thoroughly ready to appreciate the scientific features of the process and to apply it. The numerous papers contributed to the *Journal of the Franklin Institute* by Dr. John W. Draper, several years before Daguerre's discovery, detailing investigations, are classical, and surprise us even to-day by their minute accuracy and anticipation of solutions of questions long subsequent. But he escaped making Daguerre's discovery. He succeeded, however, in doing what Daguerre had not yet succeeded in accomplishing. He took the first portrait by Daguerre's process, although, as we shall note, this claim is disputed in favor of a Philadelphian. He took the first photograph of the moon. He applied the process in a variety of ways in scientific investigation. But nowhere did the announcement lead to practical application as quickly as in Philadelphia. The old American Philosophical Society and the then young Franklin Institute had members alert for anything that was new in science. Joseph Sexton took the first photographic view in America, out of a window of the Mint, with very crude apparatus in October, 1839. Robert Cornelius, a lamp-maker, took a portrait in the latter part of 1839, some claim before that made by Draper. The Franklin Institute, in its exhibition in 1840, displayed some of the first results. The *Ledger*, in its account October 12th, states: "Throughout the room are various specimens of

the daguerreotype. They consist mostly of miniatures." This shows great enterprise for a day of sailing vessels, when it is remembered that Daguerre's process had only been made public in Paris in August, 1839. But the part that Philadelphia had has been so fully treated in a lecture before the Franklin Institute several years ago by Mr. Julius F. Sachse* and published in its *Journal*, that I can do no better than to refer to it. But one fact of permanent effect, and of exceeding interest in this connection, is the strong body of amateurs in the art which sprang up in Philadelphia, and which has always characterized it; strong not only in numbers, but in scientific character and motive.

I think I am not mistaken when I assert that the first independent photographic society in America was the Philadelphia Photographic Society, as the American Philosophical Society was the earliest scientific society. It was organized in the heroic days of photography, when the practice of photography meant a great deal; when press-the-button and snap-shot work were unknown. Members of the Philosophical Society and of the Institute were active in founding it and making its creditable records. Dr. Coleman Sellers, President of the Institute, was a prolific writer on photographic subjects, always instructive and practical. Joseph M. Wilson, who is doing so much to give Philadelphia pure water, also a former president, has been an enthusiastic amateur from his boyhood. There are so many others, who have not filled that high position, active in advancing photography, that I must refrain from mentioning any, except Mathew Carey Lea, so well known as one of the most indefatigable, painstaking scientific investigators, whose contributions to this subject, largely along lines all his own, are not only of present practical value, but full of promise to investigators, which the future will doubtless realize. His apparatus bequeathed to the Franklin Institute will form a fine nucleus for the encouragement of photographic investigation. When Professor

* Sachse, Philadelphia's Share in the Development of Photography, *Jour. Frank. Inst.*, **135**, 271.

Henry Morton, then Secretary of the Institute, organized the highly successful expedition to photograph the total eclipse of 1869, under the auspices of the National Government, he was able to draw largely from the membership of the Institute for his efficient corps of observers.

But to return to the development of photography. One of the most tantalizing defects of the process, as published by Daguerre, was its slowness. It suggested portraiture, but just came short of desired success. In 1840 the requisite increase of sensitiveness was obtained by the use of bromine in connection with iodine, and the trio of silver haloids in use today was completed. This use of bromine as an accelerator, as it was called, was published by Goddard, of London, in 1840. The honor of its introduction is also claimed for Philadelphia, where Dr. Paul Beck Goddard, a singular coincidence of names, employed it as early as 1839, but, as he kept the fact a secret until 1842, whilst we are privileged to believe that he first used it, we cannot claim the honor for him as against prior publication. The process, it seems, was employed at once commercially here with greater success than in France. Daguerreotype portraits were taken at five dollars each. The Calotype negatives of Talbot, with the objectionable grain of the paper, suggested better things. Glass had been used by Herschel in some experiments with silver chloride, and negatives on glass, with albumen as the vehicle of the silver iodide, which afforded excellent paper prints, were first produced by Niépce de St. Victor, nephew of Niépce, in 1847. The daguerreotype began to recede in importance, and amateur practice of photography was stimulated. In 1850 the greatest advance since the time of Daguerre was made by the introduction of collodion, a solution of guncotton, then recently discovered, as a vehicle of the sensitive silver iodide. Glass and collodion seemed to possess all desired properties for photographic purposes. Nothing better seemed possible. The daguerreotype disappeared entirely. A collodion positive process on blackened metal, an American invention, in a measure took its place, and survives to this day as the tintype. The collodion process, however, was soon found uncomfortably cumber-

some by the growing number of amateurs, requiring as it did the completion of the whole process whilst the plate was still wet, necessitating the impedimenta of tents, bulky solutions, fragile vessels, etc., for outdoor work. The dispute continued for a decade between *humidus* and *siccus* as to the relative merits of the wet process and various dry-plate processes devised from time to time. At last, in 1862, the tannin dry-plate process of Major Russel seemed to be satisfactory in results, but slow in exposure and time-consuming in the preparation of the plates. In the wet-collodion process the metallic haloid was added to the collodion and the plate coated with it immersed in a solution of silver nitrate, where the reaction took place producing the silver haloid. The question naturally arose, why not eliminate one of the most troublesome factors of the process by adding the silver salt to the collodion? In 1865 Bolton & Sayce overcame the intrinsic difficulties, and produced an emulsion of silver haloids with collodion suitable for the purpose. The process became commercially available, and bid fair to revolutionize photographic practice. But in 1871 Dr. R. L. Maddox succeeded in producing workable plates with an emulsion of gelatine and silver bromide. The process was at once taken up, and brought by rapid stages by different workers to a high degree of perfection. Dry plates of wonderful rapidity, of great certainty and ease of manipulation and of practically indefinite keeping qualities were soon placed upon the market. Again a Philadelphian, and member of the Institute, John Carbutt, manufacturer, was among the very first to recognize the commercial possibilities of the new process and erect a plant to meet the demand sure to spring up. The professional adopted them slowly. The amateur recognized in them the long-desired dry plate. Photographic societies in the United States, mainly of amateurs, increased in the decade from 1883 to 1893 from 9 to 120, or more than twelvefold. Manufacture of cheap, but good, dry-plate outfits, which dispensed with the more expensive wet-plate holder, assumed very important proportions. Dry plates and improved developers and appliances for dry plates began to

predominate in the advertising columns of the journals, and detective cameras, as hand-cameras were generally called at first, were largely advertised in periodicals in which photographic advertisements had not appeared before. But the amateur complained now of the weight of glass to be carried. A return to paper for negative purposes was made, expensive apparatus devised to coat it and with excellent results. The critical amateur withheld his patronage. At last a substratum was produced in celluloid, singular to say with guncotton as a chief ingredient, having the essential photographic properties of glass, but tough as well as light. But still the enthusiastic, patient amateur, with almost infinite capacity for trouble, but always seeking lines of least resistance, striving to avoid the unnecessary in his work, and keenly sensitive to discomfort, complained that he had to retire to the dark-room or changing bag before his day's work was half done. Again his complaint was met by the daylight loading roll of sensitive film, which will permit a year's snap-shotting without entering the dark-room.

The discovery by Professor Vogel, in 1874, of the possibility of rendering plates sensitive to colors generally regarded as non-actinic, by treating them with suitable dyes, constituted the most distinct advance in photography since the days of Daguerre, widening its range of applications. Fred'k E. Ives, of the Institute, published the first perfected orthochromatic process. Orthochromatic plates soon appeared in the lists of up-to-date manufacturers.

The processes for multiplication by action of light have sympathized with the general progress of the negative practice, but have not kept pace with it. The direct printing out processes in use from the earliest albumen coated silver chloride paper down through the papers of various names, coated with gelatine or collodion as vehicles, with their dependence on daylight for printing and their subsequent operations, are ante-Daguerrean in principle, and almost anachronisms in this day. The developing papers, with their independence of daylight, and in the Velox-type permitting developing by comfortable gaslight, and, with suitable apparatus for exposure, yielding 5,000 prints per day, seem more nearly up to date.

But all processes with silver are viewed with distrust in regard to permanency. Two processes at least are regarded with more favor in this respect, and are recommended by the National Photographic Records Association of Great Britain for its photographs. The carbon or pigment process, which carries back in principle to the time of Niépce, based upon the discovery of Mungo Ponton in 1839, of the loss on exposure to light of solubility or stickiness by gelatine and other organic substances, mixed with alkaline bichromates. The other, the platinum process dependent upon the reduction of a ferric to a ferrous salt by light, one of the many discoveries of Sir John Herschel, and the reducing action of the latter on a platinum salt also present in the paper. The process, originally patented by Mr. Willis, now free, is simple in manipulation, and yields artistic effects as well as permanent prints. The blue print process, humblest of all, but yielding a larger acreage than all others, also originating with Sir John Herschel, is based on the reduction of a ferric salt, and as practised today, also in some degree upon the reduction of a ferricyanide.

But a thought ever present with investigators has been the multiplication of pictures by other than purely photographic methods. Niépce started with the motive of etching plates by means of light for printing. Attempts were early made to convert the daguerreotype into a printing surface. In recent years processes based on the properties of gelatine mixed with alkaline dichromates have been commercially highly successful, as photo-lithography, the heliotype, Woodburytype, swelled gelatine and washout gelatine processes, etc., some capable of rendering all the tones, others restricted to black and white, but none of them meeting the growing demand for typographic blocks capable of rendering the shades of the original. At an early day it was found that by breaking up the shades by a grain imparted to the printing surface in different ways, half-tones could be simulated, and the line screen was one of the methods for so doing. But in none of these methods was there an attempt at what might be termed a discriminating grain, a precise rendering

of the shades, as an engraver would do, by lines and dots of varying sizes and separation. In 1891, Frederick E. Ives, of our Institute, patented and conducted commercially a process that might be characterized as ideal in this respect. By it all the tones of photographs and wash drawings could be faithfully rendered by typographic blocks. The testimony most conclusive on this point, perhaps, is the criticism of the art critic of one of the leading dailies of New York, of engravings in a work which called for art of high character. To quote his words in regard to some pictures selected by him as the "finest in the book," he says: "Without detracting from the artist's meed of praise, it may be added that the most remarkable thing about these illustrations is the extraordinary skill displayed by the engravers," and he speaks of the "marvellous delicacy of precision and touch," "power of taking up the theme submitted by the artist," etc., and yet they were soulless photo-engravings by Mr. Ives' purely mechanical process. The blunder of the critic does not reflect on his professional character, but only on his ignorance of the resources of photography. This process has been largely replaced in recent years, for the requirements of the general trade, by the more facile line screen half-tone process, greatly improved by the variation and proper manipulation of the screen and stops employed, and by attention to the optical conditions involved.

Color photography, the dream of every one interested in photography, has seemed to many beset with apparently incompatible conditions, and the unattainable limit of photographic progress. It has none the less, from the earliest period, engaged the attention of the ablest investigators.

A measure of success has been announced from time to time, by Seebeck in 1810, and subsequently by Sir John Herschel, Becquerel, Niépce de St. Victor, Poitevin, Simpson and others. In all cases a difficulty in fixing the pictures has prevented a much-desired general inspection. The following extract from a letter of Sir John Herschel, in 1865, is one of the most favorable accounts: "I received a complete colored spectrum picture from Becquerel several years ago, which is still as fresh in color as when received. The

whole spectrum from end to end, if not brilliant, is still distinct. I seldom examine it, and only by lamplight." The more recent process of Lippmann, founded on interference of light, is of great scientific interest, but, if it has a commercial future, has not yet passed its experimental stage. Other less direct processes seem more practicable. The so-called Jolly or McDonough process, dependent upon a taking screen of lines in intimate contact, colored in series red, green and blue, placed before the plate in taking the negative and used in viewing the result, is also short of commercial success. The heliochromic process of Frederick E. Ives, in conjunction with the Kromskop, comes nearer the complete realization of reproduction of natural colors, and is commercially available. It requires three negatives simultaneously taken, representative of the Young-Helmholtz-Maxwell color sensations, and three positives simultaneously presented to the eyes in the Kromskop, by light through glass or screens (red, green and blue-violet) suitably colored for each. The camera for taking the negatives and the instrument for viewing the positives are ingenious and practicable. Until some process based upon some new material, or new principle, is discovered, this process is likely to hold its present place. Possibly the silver photohaloids investigated by M. Carey Lea may yet lead to the perfect color process.

The scientific world, hardly recovered from the shock of surprise at Röntgen's discovery, and undecided whether it is dealing with rays or emanations, led by it, seems entering a new and broader field of investigation, almost uncanny in some of its aspects. The terms Becquerel rays, Russel rays, metallic radiations, vaporography and the like are full of import. As stated by Dr. Crookes, "Some bodies without special stimulation are capable of giving out rays closely allied, if not identical with those of Röntgen, and it would almost seem, from the important researches of Dr. Russel, that this ray-emitting power may be a general property of matter, for he has shown that nearly every substance is capable of affecting the photographic plate, if exposed in darkness for a sufficient time." The list of active substances is a long

one, to which a recent investigator has added the human body. The rays pass through many opaque substances, and are checked by others. They excite fluorescence. Already they have led to the discovery of a new metal by Madame Curie, and named polonium, possessing 400 times the energy of uranium, which has hitherto held the highest place. It was announced in the morning paper that Prof. Geo. F. Barker has brought with him from Paris, a specimen of the new metal, and we trust we may look for some demonstration of its properties at an early day. This energy seems to be without exciting cause, and without perceptible diminution. If radiant energy, may not perfumes, which have been regarded as material emanations, be of the same character, and the rose emit rays that will affect a properly sensitized plate?

This hasty résumé of some of the leading facts in the growth of a branch of science, the history of which practically begins with that of the Institute, to which the occasion more naturally invited than to a display of its achievements, would find its highest justification in the enumeration of its applications. But a very few must suffice. In scientific investigation the eye has been replaced in so many cases by the camera, for observation as well as record, that we begin to inquire what is left for visual observation. This is not for the relief of the eye, but because the photographic plate has so much wider range in time and space. It is capable of observing the instantaneous, and yet of looking without wearying, but with cumulative effect by the hour to catch phenomena to which the eye, with its best aids, is hopelessly blind. It has even been said by an eminent astronomer, that it has added to observing power as much as the invention of the telescope. It has, in fact, revolutionized astronomy. Beginning with the moon, with which perhaps least has been accomplished, total eclipses of the sun have yielded up long desired information, otherwise unattainable, so that they, by comparison, approach the character of worked-out fields. Automatic daily observations of the solar surface, with the details of its

spots, promise data for determining effects upon terrestrial climate. Nebulæ have been discovered, their form, details and conditions revealed, and fainter extensions, vaster than could be conceived, added. Comets have exhibited wonderful transformations, distortions and internal movements utterly undiscoverable by the best telescopes alone. Asteroids so numerous leave the record of their existence in trails upon the plates that, as has been said by Professor Barnard, they are turned adrift again unless they show some striking peculiarity of orbit. Meteors record their paths on which rests the expectation of precise determination of the radiant. Combined with the spectroscope, binaries of shortest periods are detected, variable stars not only discovered, but classified. The surmises of mathematicians in regard to Saturn's rings are confirmed. Runaway stars are caught. The Parisian astronomer that could not catch the satellite of Neptune with his telescope, could see it fixed on his photographic plate.

Photography and the microscope, too, have gone hand-in-hand with a more intimate sympathy even than that between the camera and the telescope. Among the earliest amateurs of highest character was a large percentage of experts with the microscope. It was in the decade following the founding of the Institute that the microscope began to assume something of its present character as an instrument of delicacy and precision. In 1831, the factory of Ross was established, and under the stimulus and coöperation of such men as Herschel, Airy, Powell, and more especially Lister, improvements in the optics and mechanics of the microscope were rapidly made, so that at the discovery of photography, microscopy had an entirely modern aspect, and it recognized at once a new ally. Dr. Draper immediately took microdaguerreotypes. From this time the improvements in optical appliances urgently demanded by the microscopist were ably seconded by the photographer, and both combined were largely instrumental in occasioning the marked progress in practical optics, which, in turn, reacted to advance photography and microscopy. Even in the days of slow wet-collodion good work was done with the microscope, and even

stereo-photo-micrographs were taken by Professor Rood. The rapid dry-plate, sensitive to all or any desired colors, has nowhere contributed more to the advance of photographic practice than with the microscope. It has become to it only less the observing and recording eye than to the telescope. The intimate connection between the microscope and the camera is also well exemplified in the Institute, where the gifted Zentmayer gave the world its best model for the microscope, and the lens which bore his name long filled a place entirely its own in photography, and when the Government placed the administration of the total eclipse expedition of 1869 in the hands of Professor Morton, then Secretary of the Institute, it was unnecessary to seek further for the complete solution of the then new practical optical questions involved in such an enterprise.

In chemistry, Dr. Crookes, by aid of photo-spectroscopy and orthochromatic plates, has added the metal monium to the list, with its characteristic lines far out in the ultra invisible light, in the phosphorescent glow of yttria under molecular bombardment in vacuo. Meteorological science is enriched by photography. It is pertinent to mention the interesting contributions of W. N. Jennings, of the Institute, to the study of lightning discharges, and the work of C. Francis Jenkins in the conversion of a scientific toy into the phantascope, which has found its extension in the kinetoscope, and which earned for him the Cresson medal of the Institute. The kinetoscope, with its miles of photographic films, as exhibited first by our H. R. Heyl, has found applications unanticipated in recording the movements during a solar eclipse and of growing plants, and has gone to the front with the army in Africa. In the industries the applications of photography are of infinite variety in character and importance. It is proposed to furnish cards for the Jacquard loom, and thus make tapestries commonplace. It will furnish water-marks for paper capable of 100,000 impressions. It reproduced the Encyclopædia Britannica at one-third the cost of type. It preserved the valuable MS. copy of Century Dictionary, which was practically uninsurable, in miniature form against loss by fire. It may, in the

future, in the same way, find a place to economize shelf-room in our libraries by compressing books that are seldom or never read. Its applications are well known in the copying of inscriptions, even in dark interiors, in the preservation and duplication of valuable documents and papers, in the detection of forgeries, especially by the method of composite photography as developed by Dr. Persifor Frazer, in the furnishing of legal evidence in general, in the detection of criminals, etc. In Canada, 50,000 square miles have been platted by means of the photo-theodolite. In the late war the camera went to the front, and has furnished invaluable records Apropos to this, it is only necessary to recall Capt. Wise making exposures whilst charging up San Juan Hill. In the present African war it promises to play an important part in reconnoissance through the telephoto apparatus that accompanies the British forces.

In its purely commercial aspects this subject is one of growing importance. The demands, at present great, are rapidly increasing with new applications and expansion of those now in use. Outside of the industries consuming photographic goods there are at least 1,500,000 amateurs in the United States, generally regarded as gross consumers. The industries supplying photographic wants are necessarily of the most varied character. Companies supplying them are continually increasing their plants. It is difficult to get at the amount of business and profits, but the published statement of one company originating in America, now in England and America, announced a dividend of 20 per cent. in December last, with repeated interim dividends, on a capital of $8,000,000. Other companies show similar prosperity. One article, largely consumed, may be particularly mentioned, which America does not seem able yet to produce of best quality, namely, paper, and it is well for manufacturers to remember that in photography only the best of everything is good enough.

Mining and Metallurgical Section.

THREE-QUARTERS OF A CENTURY'S PROGRESS IN MINING AND METALLURGY.

By Chas. Kirchhoff,
Editor *The Iron Age*, New York.

[An address delivered in Convention Hall, National Export Exposition, Wednesday, October 4, 1899, on the Occasion of the Celebration of the Seventy-fifth Anniversary of the Franklin Institute.]

It is with swelling pride that we may pause to look over the achievements in mining and metallurgy during the past seventy-five years. Within that brief span, which, as we reckon generations, has extended over only two and a half, there have been created our great industries of to-day. Our country may look back over what has been accomplished with satisfaction, even if we admit frankly and fully that we have been blessed with extraordinary resources. It may seem almost crude to gloat over mere arrays of figures, and the reproach, occasionally made, that we worship quantity unduly, has some justification, yet the record is an amazing one, nevertheless. A more serious criticism is that we have been prodigal of our heritage. Let it be admitted that we have been, and are even still, in some respects, wasteful and extravagant. Much of that reproach vanishes, however, when the conditions are taken into account. In the arts, in engineering and in manufacturing, after all, it is the balance-sheet which rules, and, from an economic point of view, waste may be not alone justified, but be actually imperative.

It is difficult to measure progress, qualitatively, in branches like mining and metallurgy. It is expressed in the more complete utilization of the natural resources, as in the increase in the total extraction of the contents of a coal bed. It is in evidence in the form of a capacity to utilize bodies of ores, lower and lower in grade. It is proven by ability to produce from rebellious, or impure ores, metals nearly chemically pure, and commercially available for a

wider and wider range of consumption. It finds expression in the disappearance of the supremacy of the brand, only too often the creature of fortuitous circumstances. It is measured by an expansion of markets which may be due to the fact that technical progress has proceeded more rapidly in one country than in others.

For these reasons a simple enumeration of statistics of production only partially reflects the development of an industry. Yet that in itself shows a record of which we may well be proud.

Practically seventy-five years ago our greatest mining and metallurgical industries were in their infancy, and many were not even started. We had only begun to mine small quantities of anthracite coal. We were producing iron, but had at an earlier date been relatively more important as an iron-manufacturing nation. Silver, copper and lead were made in irregular, very small quantities. Zinc was not produced, and the gold output, with the Georgia gold rush of 1828–1830, was about to begin. In other words, our mining and metallurgical industries were of so limited a character that, compared with the ancient operations of the leading European nations, they were insignificant to a degree.

While it is true that our miners and smelters rose to the occasion when they were called upon to meet special conditions, the general fact is apparent, from a study of our development, that we first copied and then adapted the methods approved by experience in Europe. We were forced and did create hydraulic mining to collect the gold from alluvial deposits. We developed the preparation of anthracite for the market. We had nothing to guide us in handling the copper rock of Lake Superior. The Washoe process was worked out to treat the silver ores of the Comstock lode. There were few precedents for methods in the petroleum industry, and had to learn by ourselves how to collect, distribute and utilize natural gas. But Cornish, Welsh and English miners long controlled the working out of our mining methods. German and English metallurgists guided our first steps in beneficiating our more complex silver, lead and copper ores.

One of the most brilliant reports on the state of the art ever written, that of Abram S. Hewitt on the Paris Exposition of 1867, is a confession of superiority of European methods in iron manufacture, which is almost staggering to one who reads it in the light of the present day. I cannot help feeling that the recognition of our indebtedness to European practice in the earlier days should be insisted upon, since it is becoming altogether too common to assume that we are the chosen people so far as the mechanic arts are concerned. Many of you have, undoubtedly, like myself, encountered that feeling in such places that the fear of the danger of overconfidence is naturally aroused.

A striking fact is the growing interdependence of the various branches of the mechanic arts as contrasted with the conditions prevailing seventy-five years ago. The one relies upon the other, not alone for its products, but is aided too by suggestions and support. The metallurgist's progress is accelerated by the mechanical engineer, and the latter looks to the former for increasingly strong and reliable materials. The electrician has greatly widened the capacity for improving methods on the part of the copper producer, and in turn is under a debt to him. The cheapening of fuel, due to the efforts of the coal miner, and the achievements of the rail-maker, are returned in kind by the railroad builder, who has taught both much of value in transporting materials. Thus, all are shoulder to shoulder in the march of progress, mutually helpful and united—all-powerful.

To a constantly-increasing degree pure science, primarily in search of the truth for its own sake, sheds its searchlight along the path, and has become a closer and more valued ally year by year. Many of us will recall how the majority of active workers looked askance at this meddler, preferring to allow their own fancy full sway whenever they stopped to seek for causes or explanations. We may sometimes become impatient when the laborious and apparently hypercritical methods of the scientist do not more promptly clear an obscure point, or furnish us with a suggestion for suc-

cessful new lines of work, but the day has long passed when we treated research with grudging respect, if not with open hostility. No one is now readier to acknowledge his indebtedness to the chemist or the physicist than the manager or the practicing engineer. The fear is disappearing of impracticable science on the one hand, and of unscientific practice on the other. And foremost in the work of harmonizing both in this country has been the time-honored body whom you, Mr. President, represent. The splendid array of the volumes of the *Journal* of this Institute is, in itself, the greatest monument to the man whose name it bears, and to those who have labored in pursuing in his spirit the promotion of science and the arts as a means toward promoting the happiness of mankind.

MINING.

With the widespread search all over the world, and the increasing number of trained observers, there has been an enormous accumulation of observations and data relative to mineral deposits. In the case of bedded deposits, the relations between mining development and economic geology have become closer and closer. But, on the whole, it cannot be said that this branch of science has given much direct aid to the metal miner. The systems of extraction have not undergone any radical improvement. On the whole, they are modified more frequently to meet more closely local conditions. It is rather in the work of excavation proper that progress has been most striking. It was J. J. Couch, a Philadelphian, who, in 1849, patented the first percussion drill ever made. Herman Haupt experimented with rock drills at the Hoosac Tunnel, from 1856 to 1861, while the first drill tried in mining was that of Schumann at Freiberg, in 1857.

Colladon had proposed to use compressed air to work drills as early as 1852, but general attention to rock drills driven by compressed air was attracted by their employment at the Mont Cenis Tunnel in 1861, the plan to adopt them having been approved in 1857, as the result of Sommeiller's work. Quickly following upon the start thus made

by power drills, came the introduction of high explosives. Nobel first applied nitroglycerine in 1863, and its use was begun in 1866 at the Hoosac Tunnel. A year later Nobel introduced dynamite, and since then power drills and high explosives have wrought a complete revolution in mining, by increasing the speed of development and extraction, by very greatly increasing the efficiency per man employed underground, and by heavily reducing the cost. By constant improvement in design and detail of both compressor and drill, machines have been created which have a wonderful life and efficiency, considering the adverse conditions under which they are expected to operate. What the defects in design in the early days meant is illustrated by the fact that in 1864, in the Mont Cenis Tunnel, it took an equipment of seventy Sommeiller drills to keep eight steadily at work, and in 1867, 200 were needed to maintain sixteen in actual operation.

The mechanical engineer and machine builder have given their powerful aid, too, in improving pumping and hoisting machinery. The simple and effective American direct-acting pump has done valuable service to mining, although for heavy service and large quantities of water it is giving way to more elaborate engines. In hoisting appliances, for deep mining we long remained behind European practice, our shallow mining not calling for heavy engines. During the last decades, however, some splendid equipment in magnitude, in speed and in economy of operation has been designed in this country, some of the greatest of these engines having been built in this city.

Underground traction has undergone far-reaching changes. Wire-rope haulage was introduced into collieries long before San Francisco led in surface cable traction, and in this country pneumatic and electric haulage were very promptly adopted and very rapidly developed. These, however, are only recent achievements, progress in underground haulage having been very slow for decades.

In timbering the Comstock square set was a characteristically American creation to meet exceptional conditions, and it is true that the preparation of mine timbers above ground by machinery was first practiced in this country.

For a long time the concentration of ores was neglected, simply because in many remote sections in the United States it did not pay to turn to mechanical dressing and because the oxidized surface ores, easily smelted, did not offer opportunities. An exception must be made of the Lake Superior copper region. There the Ball steam stamp quickly superseded the time-honored battery. Subsequently, Leavitt reduced the steam consumption by compounding, and more recent practice has proven that the spring foundation is not equal to the solid anvil in bringing out the highest efficiency. Ore concentration has been well developed in later years in Southeastern Missouri, and the low-grade lead and copper camps of Colorado, Utah, Idaho and Montana.

It would be a serious oversight, in dealing with the treatment of ores, to overlook the enormous influence which the introduction of the Blake crusher has wielded in the efficient handling of rock. Nor should later types of crushers, like the Gates, be overlooked.

An example of steady progress in crushing apparatus is furnished also by what is known as the California stamp mill. Every detail has been watched and worked out for decades, and a number of efficient self-feeding appliances have been added, until to-day there are enormous plants pounding away year in, year out, without any intermission, with merely a crew of inspection to represent the labor account.

It seems certain that the part which the rock drill has played in general mining is destined to be paralleled in coal mining by the modern coal-cutting machinery. The difficulties inherent in handling mechanical apparatus in low rooms may account for the fact that progress has apparently lingered so far behind in this field. In Europe, as well as in this country, inventors took hold of the problem in the fifties, but little headway was made for many years. It is only quite recently that machinery for this purpose is being introduced with a rush. Among the pioneers were Harrison with a pick machine, and Lechner with a cutter-bar machine. All the earlier types were driven with compressed air, and it was not until 1889 that electricity was applied to

the Jeffrey cutter bar machine, since superseded by the electrically-driven chain breast machine. How rapid has been the development of this branch of work in this country in recent years is shown by statistics compiled by E. W. Parker, of the United States Geological Survey. In 1891 6,211,732 tons of coal were mined by machines representing 6·66 per cent. of the whole. In 1898 the tonnage had jumped to 32,413,144 tons, or 20·4 per cent. of the whole. It is not too much to say that, from an economic point of view, this is the most far-reaching and significant recent development in mining.

A splendid achievement in mining was that of handling auriferous sands by hydraulicking. I do not remember ever having noted in our literature any definite data which might fix the credit for this upon any one man or group of men. The date is placed at about 1853, and in those stirring times, so soon following the discovery of gold in California, probably no record was left. The further stages of its development are coupled with the names of a number of inventors of nozzles and many ingenious hydrodynamic and hydrostatic contrivances, and in its greater days, before the anti-debris laws in 1882 cut off the work, bold and splendid engineering work was done in connection with these undertakings.

In more recent times some very thorough work has been done in one branch of ore dressing, and that is, in magnetic separation of iron ores. A number of American inventors, among them Ball & Norton, Wenstrom, Wetherill and Edison, have labored to utilize the lower grades of magnetites in the Eastern States. The problem of cheap and effective crushing involved has been carefully studied and brought out new ideas, but economic conditions for a while pushed the whole undertaking into the background. Recent events point to fresh opportunities in this direction.

METALLURGY.

Gold.—In the metallurgy of the precious metals marked progress has been made, although no really revolutionary methods have come to the front until the present decade

brought the cyanide process. In gold extraction the improvement in the California stamp mill, largely mechanical, has already been alluded to. There have been added, in the amalgamation process, some ingenious contrivances, but it was not until the experienced chemist drove out the horde of so-called "professors" and charlatans that the treatment of auriferous concentrates and pyrites was a success. The chlorination process, together with the improvement in the design and operation of the batteries, and the introduction of the Frue vanner and machines of its type, has rendered possible the profitable treatment of very low grade ores. These are to-day prosperous enterprises based on a yield of $\frac{1}{10}$ of an ounce of the yellow metal to the ton of rock—a quantity so minute that no gold is visible in the ore, week in, week out.

The chemist again has intervened in recent years. While the solvent power of cyanides on gold was known early in this century, it was not until the later eighties that the McArthur-Forrest process made that method practicable by utilizing the fact that zinc shavings may be used as a precipitant.

For the treatment of more complex ores there was developed relatively early, at the Argo Works in Denver, a series of methods dependent upon the employment of copper as a carrier, and more recently pyritic smelting is gaining ground. It is based upon the treatment of sulphide ores in the blast furnaces, so that a considerable part of the heat produced by their oxidation is utilized in their fusion. Small quantities of lead or copper serve as collectors of precious metals.

Silver.—Although the patio process of amalgamation was invented in 1557 by Bartolome de Medina, at Pachuca, followed in 1590 by the cazo process of amalgamation invented by Alonzo Barba, at Potosi, no real improvement followed in the succeeding centuries. On the heels of the discovery of the Comstock lode in 1859, by O'Reilly and McLaughlin, came the invention of what is known as the Washoe process of amalgamation, by Almarin B. Paul and James Smith. On the oxidized and chloride ores of the surface

it did admirable work, but, as the more rebellious material below drainage lever appeared in growing quantities, auxiliary operations required growing attention, the Augustin, Ziervogel and Patera processes, brought out from 1843 to 1858 in Europe, having been used only locally here. It was in the direction of improving the chloridizing roasting that metallurgists sought and found a solution of their troubles. Brueckner, Stetefeldt, Howell, O'Hara and others did admirable work, but with the steady improvements in lead smelting, increasing quantities of the rebellious silver ores were diverted from the amalgamating mills to the smelters, and now silver milling has shrunk to a secondary place.

Lead.—Although lead mining was begun as early as in the days of Law's famous Mississippi Company, and Mine La Motte, in Southwest Missouri, still in active operation, was discovered at that time, yet production did not develop seriously until late in the twenties. It attained about 10,000 tons per annum in 1833. With the rich and pure ores the Scotch hearth served admirably and remained the standard method until the discoveries in quick succession of the rich ore bodies of Eureka, Nevada and of different camps in Utah, late in the sixties, led to the copying of German blast furnace practice. Arents, Eilers, Hahn, Grant and others soon introduced improvements, Arents' siphon tap being a very important step forward. Water jackets appeared and a thorough scientific study of the chemical composition of slags led to more regular and cleaner working, and the collection of flue dust assumed growing importance, Iles, of Denver, doing conspicuous work in this direction. Charcoal as a fuel gave way to coke—the quantity of lead in the smelting charges needed to cover the precious metals was steadily crowded down under the pressure of a scant supply of lead-bearing ores. With the steady development of the railroad system of the Rocky Mountains, dry ores carrying little or no lead became available in larger quantities, and to-day American lead smelting plants are models for the world.

As an incident of progress in another direction may be mentioned the Bartlett process, for the direct production of

white oxide for paint in successful operation at Joplin and at Canon City. In lead desilverizing and refining, a modification of the Pattinson process, invented in 1833, found only a passing application. Soon after the argentiferous base bullion of the Rocky Mountains made their appearance, the Parkes zinc process, invented in 1852, was first introduced at the Balbach works at Newark, and the most important improvement in it was that of the Faber du Faur furnace for distilling the rich zinc alloy. Since then progress has taken the direction of economic handling of large charges and the introduction of labor-saving appliances.

Copper.—Although some copper was mined along the Atlantic coast at a number of points in the eighteenth and during the earlier part of the present century, it was not until the gradual opening up of the Lake Superior region from 1845 onward that it attained the dignity of an important industry. Curiously enough, it was in the same year that the smelting industry on the seaboard was started by the Revere Copper Company and the Baltimore and Cuba Smelting and Refining Company; both depended almost entirely upon foreign supplies of raw material. These flourished for about twenty years, and then collapsed or led a precarious existence until domestic supplies of furnace material from the Rocky Mountain region caused their revival. To-day our tidewater plants are among the great works of the world, and have begun to again draw heavily from foreign sources. Thus, Australian black copper comes to us *via* London for treatment, to be returned to the European markets, and Chili bars are making the same journeys. Metallurgically, there is little to remark concerning the development in the treatment of the native copper of the Lake region, which held sway in the markets for so many decades. The time-honored methods of refining continued with little change, although effort was made to introduce the Siemens open-hearth furnace.

A new era began with the opening up of the oxidized deposits of Arizona and the ores of the Butte district. In the former the water-jacketing of the furnaces was one of the first successful steps, and a general improvement of practice

followed quickly. In the Butte district a good deal of tentative work was done in concentration, in roasting and in smelting in reverberatories and in blast furnaces. The Brueckner, Brown and Wethey roasting furnaces were adopted, and the Manhes process of bessemerizing, invented in 1883, in France, was first introduced at the Parrot works. The practice has been improved very rapidly, and now the remelting of the matte is being superseded by direct transfer from the furnace to the converter. Almost simultaneously came the electrolytic process of separating the precious metals, in which very rapid progress has been made, and which, coupled with the bessemerizing, an economic revolution has been effected, not alone in cost of production, but also in the direction of furnishing a high-grade metal from impure ores.

Iron and Steel.—And now we approach the greatest of all metals, iron, in the development of which this State has had so conspicuous a share. It would be presumptuous in me to even sketch its course, who have been a mere onlooker during the past twenty-five years, when there is with us one who has lived through its most glorious period and has had so commanding and conspicuous a part in the great deeds of American iron-makers and engineers.

After all it was not until the days when John Fritz became a leader that the marvellous development was initiated. Remember that it was not until 1839 that anthracite was used in the blast furnace, and that six years later raw bituminous coal was tried in this country as a furnace fuel. You must recall that boiling was only introduced in 1848, that our modern steel-making processes did not really occupy a commanding position until late in the sixties, and you will realize that the great period of the iron industry is really concentrated in the last thirty years.

One fact perhaps you will allow me to dwell upon, and that is, that the Bessemer process really forced a recognition of scientific work upon the attention of the practical iron-master. The chemist very soon became a part of the force of the steel works, and somewhat later of the furnace plants, who were anxious to have them as customers for pig iron.

Not that chemical research had not long since been directed to metallurgical operations, and not that a few did not indulge in speculations as to the scientific causes of observed phenomena.

It was only lately that I came upon striking evidence of that in David Mushet's classical work on "Iron and Steel," printed in 1840. The following passage is characteristic:

"The quality of air during the summer months becomes much contaminated from combustion; by holding in solution a much greater quantity of moisture, the abundance of nitrous particles may also diminish the usual proportion of oxygen. This will account for the inferior effects of combustion, both in common fires and in the blast furnace. It will also in a measure tend to solve the curious phenomenon of pig iron taking up less carbon in summer, although reduced with a superior quantity of fuel. The air discharged most probably contains less oxygen, yet the metal is much less carbonated than at other times when contrary proportions exist. Most probably the deficient carbon is carried off by dissolving in hydrogen, forming a constant stream of hydrocarbon gas, while the oxygen that is free unites to the iron, and while it reduces the quality, at the same time the quantity is reduced by a portion of the metal being lost in the scoria."

It is thus that one of our pioneer metallurgists seeks an explanation for the fact that furnaces are apt to make off grade irons in summer—a phenomenon which is said to have become a marked one in this boom year 1899.

Recent history in the branches of the mechanic arts records many instances of the powerful aid which theoretical investigation has offered to them. One of the most conspicuous was von Ehrenwerth's heat calculations in connection with the basic Bessemer process, which established the role which phosphorus is capable of playing as a substitute for silicon as a heat agent. Nor should that promising field be overlooked which microscopic investigation holds out. Possibly in that respect twenty years since our groping may appear not unlike that which Mushet's appears to us now.

But progress during the last seventy-five years has been

pushed along lines as important in their way, as the cheapening of product, or the raising of the standard of quality. Like in other industries, the captains of ours have displayed increasing care of their armies of men. It has become an axiom with every enlightened manager that every means which shall render more satisfactory the surroundings of the workers is bound to tell upon the results of their labor. Compare our modern plants with those of former decades, of which some even survive now, and note what attention is paid to make the conditions under which manual labor is performed as tolerable as the circumstances will permit. There has been a tremendous improvement in this direction, and it does not lessen the achievement when we frankly acknowledge that it is largely due to the recognition of the fact that progress in this direction pays handsomely.

Let me go a step further, and that is, that the crowning glory of the efforts to improve our mining and metallurgical industries has been that they have contributed their full share to the development of this materialistic age. They have helped to bring within the reach of an ever-growing circle of people not alone the necessities, but also many of the comforts and some of the luxuries of life. Let me confess that it seems to me the greatest and most commendable of achievements to raise ever so little the mass of humanity in civilization, and that is what progress in the mechanic arts during the past century has accomplished in a striking manner. Start the masses on a higher plane—level them up. The great genius may not tower so far above them as once he did, but that is again in harmony with our democratic institutions. Let there be an increasing equality of opportunity, even though it makes the struggle fiercer and fiercer, if only public conscience will demand with sterner emphasis that the means for achievement be fair.

It was the keynote of Franklin's life that all his thoughts and all his endeavors were directed to making his work of benefit to the human race. Although those who have labored in our fields may not have done so as consciously or as deliberately as he, the fact is that progress in mining and metallurgy has powerfully contributed toward that end.

THE DEVELOPMENT OF IRON MANUFACTURE IN THE UNITED STATES IN THE PAST SEVENTY-FIVE YEARS.*

By JOHN FRITZ,
Bethlehem, Pa.

[An address delivered in Convention Hall, National Export Exposition, Wednesday, October 4th, on the Occasion of the Celebration of the Seventy-fifth Anniversary of the Franklin Institute.]

I have been requested by your President, Mr. Birkinbine, and also by Mr. Christie, Chairman of the Mining and Metallurgical Section of the Institute, to give some reminiscences concerning the progress that has been made in iron and steel metallurgy in my lifetime and during the lifetime of the Franklin Institute.

This being the last year but one of the century that has done so much to change the face of society, and for the betterment of mankind, it will be interesting to take a brief retrospective view of the events that have taken place during this remarkable period, and in doing so we witness the most wonderful progress that has been made in the advancement of the arts of science and civilization, all the effects of which are far-reaching.

In the very front we see the phenomenal progress that has been wrought in all the various branches of manufac-

*[INTRODUCTORY.—It was my intention to have given a brief account of the early experiments with the Bessemer process at Cambria and Wyandotte, and also a brief notice of the earlier works that went into the business; I soon found, however, that it was not possible to do so in a paper such as I was called on to read, and, besides, Mr. Wm. F. Durfee and Mr. R. W. Hunt, who each by turns had charge of the experiments at Wyandotte, have already put the general results on record. Consequently, I will confine myself to such a paper as I was called to give—some personal reminiscences of my connection with the manufacture of iron and steel, which is unfortunate for me, as I would much prefer to tell what others have done than what I have done myself. But, as I was asked to do this by the officers of your society, and did not seek the honor, I beg you will, as far as possible, excuse much that will doubtless seem egotistical, and ask you to bear in mind that what I have to say is only a general history of the early developments of the iron and steel industry in this country, with which others also had much to do.—J. F.]

ture in all parts of the civilized world. We look again and find that the manufacture of iron is in the lead, and that the United States comes in for a large share of this all-important branch of manufacturing industry, which is the advance guard of civilization, one which has done so much to build up this country and served her so well both in peace and in war.

While I have not been asked to say anything about matters beyond the date of my own experience or the life of the Institute, it seems necessary, however, that a brief allusion should be made to the first puddling furnace and plate mill that were erected, in order that the great advance that has been made in this branch of the manufacture may be more fully appreciated.

The first puddling furnace in this country was built at Plumsock, on Redstone Creek, about midway between Connellsville and Brownsville, in Fayette County, Pa., in 1817. A flood caused the partial destruction of this mill. The machinery was subsequently removed to Brownsville. In 1819 a rolling mill was built at Pittsburgh in which there were four puddling furnaces. This mill was accidentally blown up, and permanently dismantled in 1829, and the machinery was taken to Covington, Ky. Both enterprises thus seem to have ended in disastrous failures.

About 1810 Isaac Pennock built a rolling mill (at that time called a "slitting mill") near Coatesville, in Chester County, Pa. In 1816 it came into the hands of Dr. Charles Lukens, a son-in-law of Isaac Pennock, and was operated by him until his death in 1825. It was during this period and on this mill that the first boiler plate was rolled in this country. The blooms were heated on a grate fire and the rolls were driven by an old-time undershot water-wheel. When a boy I heard the older men say that the mill was often short of power, and frequently all the workmen would run and get on the buckets and tread with them, in order to prevent a stall which would have caused fire cracks in the rolls, and, sooner or later, a broken roll. This being before the days of railroads, coal was hauled from Columbia, thirty-five miles distant, and the plates were teamed to

Philadelphia, thirty-five miles away, and were shipped without being sheared. A notable circumstance about these works is the fact that they have always remained in the family of Isaac Pennock, and are now operated by his descendants of the fourth generation.

What I have now said will be sufficient to give you some idea of the condition of the trade at that time, and will enable you better to appreciate the great improvements that afterwards were made; and also brings us practically down to the birth of the Institute in 1824.

From 1824 until 1836 but little progress was made in the way of marked improvements. During the thirties there were some puddling furnaces built, to puddle run-out or refined pig metal, and eventually they got in the way of using some close grain pig iron in connection with the refined metal.

In the early forties puddling began to come into general use, but only close iron was used. In the years 1844–45 the manufacture of rails commenced. This at once gave it the leading position in the manufacture of iron, which it held until it was beaten by the Bessemer process, to which I shall refer again.

About this time the manufacturers' trouble begins. The demand for puddlers soon exceeded the supply, and they thought they ought to have things their own way. Up to this time the old-fashioned Welsh hammer was the only mode in use for putting the puddled ball in shape for the rolls. The hammerman or "shingler," as he was called at that time, was the king bee, and when he went wrong, as he frequently did, the puddlers had to quit work until such a time as Mr. "Shingler" was ready to go to work, which sometimes required several days; and when at work woe be unto the puddler who might happen to be on bad terms with him.

The hammer striking a uniform blow no coaxing could be done; consequently great skill was required during the first few strokes of the hammer to keep the ball in such shape that it could be edged and upended in order to get a good-shaped and compact bloom. Should the "shingler"

fail in this, which he could and at times did, and that without any apparent intention, then a row was started which sometimes ended in a fisticuff, as we had bullies in those days as well as now, but not so well trained, and the rules of the ring were not such as they are to-day; if they had been, they would not have been strictly adhered to.

The next improvement in this line was the introduction of what was known as the "crocodile" squeezer, which was entirely unlike the hammer in every way, and it was so easily worked that almost any of the puddlers could put their own work in shape; but, unfortunately for the manufacturer, they could coax a ball into shape that was not properly worked in the furnace. So, while this was entirely satisfactory to the puddler, it was very unsatisfactory and unprofitable to the manufacturer, with the result that there was constant bickering between the employers and employés; a condition of affairs that should not exist.

Next came the "Burden" and "Winslow" squeezers; the latter was used for a time, but finally the "Burden" came into general use, and is to this day as nearly perfect a machine for the purpose intended that has ever been devised. Not alone on account of its simplicity in construction and the perfect manner in which it does its work, but because, also, it establishes justice between the ironmaster and the workmen from which there is no attempt to make an appeal. When a ball would break, the workman, without saying a word, gathered together the pieces and took them back to the furnace and worked them into a proper condition, and in the end the squeezer proved to be the puddler's friend. Notwithstanding all its good qualities, its introduction caused strife in practically all the mills that introduced it down to about the year 1856. Some of the strikes were long and bitter, and many incidents might be recited in relation to its introduction, some amusing, some ridiculous and others revengeful. However, soon after the system came in general use, an armistice was agreed upon, which finally resulted in a treaty of peace, which was advantageous to both parties.

In or about the year 1848, boiling came into general use,

which was a great improvement, and puddling soon became the all-important branch of the great iron industry of the country, and continued in the lead until it was overtaken by the almost magical invention of Sir Henry Bessemer, to which I shall refer later.

Until 1840 all the pig iron produced in the United States was made with charcoal. My first connection with a furnace dates from 1839. It was driven by water, a wooden blowing-cylinder connected with the crank by a wooden beam. The crank, the journal and the wings that were fitted in the end of the water-wheel shaft to carry the wheel and to drive the blowing-cylinders. Neither of the journals were turned off, but were put to work just as they came out of the sand. It was blown by an open tuyere. The whole plant was of the crudest construction. The weekly make was about sixteen to twenty tons. It was placed against a bank, level with the tunnel-head, so as to avoid hoisting the material up. This was about the character of the furnaces in general use at that time.

I was sent there as a "cub" to put up a belly-pipe which was made at the shop in which I was learning my trade. When it was put in place it was, as I remember, about six or eight inches too short, and I supposed somebody had made a mistake in the length. The founder was a consequential-looking man, and quite stout, with a blue flannel shirt and his "pants" held up by a rather broad leather band buckled around his body, somewhat in the order of many we see to-day, but was not gotten up in the same style. He said rather brusquely that "it was all right." The pipe was connected at the rear end to the main pipe by a short leather connection, which I was told was to allow the belly-pipe to swing out of the way so that they could get the cinder out.

This was the general condition of the furnaces until 1840, when Mr. David Thomas, since affectionately called "Father Thomas," made the first anthracite iron in a commercial way that was made in this country. This was the commencement of the phenomenal development of the blast-furnace practice that has taken place in the latter part of this century.

We left the rolling mills in 1824 in a very crude condition, and there was no marked improvement in them until the manufacture of rails commenced, which, as already mentioned, was about 1844. But even at this time the plans of the mill and manner of building practically remained the same, being geared, and it seemed to me that the general impression amongst the rolling mill proprietors was that the more wheels they could get in the better was the mill. Down to this time the carpenter or millwright had largely the say, consequently wood was much used. The shafts were generally made square, and the fly-wheel and gear-wheels were secured on them by the use of wooden wedges, into which other thin wedges of iron were driven. No matter if the foundation was built of wood or stone, a large piece of timber was placed on top, to which the housings were secured; the idea being that it was essential that the train should have some elasticity in order to take the shock off the machinery, thereby preventing breakage.

After the manufacture of rails commenced in 1844 more rigid and better workmanship was required. The mills, as heretofore, were all geared, but the carpenter and millwright were superseded by the machinist. The shafts were now turned up, wheels were bored out, and the mill all fitted up in a more workmanlike manner.

From 1845 to 1856 there were but few improvements made, either in machinery or the manner of rolling, except the introduction of the rail-straightening machine which took the place of the sixty-pound sledge and a special man to handle it. When he wanted a rest the works had to come to a standstill until such a time as he was completely rested, sobered up, or restored to health, as the case might be.

The year 1857 is a memorable period in the history of the manufacture of iron. As before stated, in 1844 the forge carpenter and millwright were superseded by the machinist, who now comes to the front as a mechanical engineer, not full fledged, but with an amount of knowledge gained by experience which qualified him for the important duty which awaits him.

As I have already said, the year 1857 was a memorable period in the history of the manufacture of iron. Down to this time all the rails were rolled on a two-high train, the pile being passed back over the top roll, which meant a great waste of time and loss of heat. When the flanges once began to crack, which was one of the serious troubles, being all the time rolled in one direction, it greatly aggravated the difficulty. The result was that when an imperfection occurred in the flange, the trouble increased with each pass through the rolls, and so extended that it was a common occurrence for the flange to tear off the whole length of the rail and wind around the roll, forming what, in rolling mill parlance, was called a collar, which very generally ended in breaking some part of the train and often the roll.

The iron was frequently both red- and cold-short and all other shorts, and in addition to this would stand but little heat, consequently the end of the pile which entered the roll first would split and open out like the mouth of an alligator. Then, of course, it would not enter the rolls without force, which was applied with the buggy, using it as a battering ram. After making several vain attempts to get it to enter the rolls it very frequently had to be turned end for end. The loss of time taken up in going through all this was such that it was almost an impossibility to get a perfect rail. Had it not been for the use of putty, oxide of iron and the absence of inspectors there would have been but few rails shipped.

In order to get over the difficulty of the flanges tearing off we went to quite an expense. Some iron of a better quality was used for the flanges, which, in a measure, gave some relief in that direction. But the iron being much stronger, required more heat and greatly increased the difficulty of opening the end of the pile in the first few passes. We were now in a sad dilemma, and something had to be done. I was sick at heart, and had it been manly I would have run away.

But, during all this time, I was giving the subject much consideration, and had fully made up my mind that, if a

three-high mill could be made to work, the difficulties could all be overcome; I, besides, had made up my mind that it was the only proper way to roll iron.

I was now prepared to suggest the building of a three-high mill, which I did; and the suggestion was met with a rebuff, which was not unexpected. They said in substance: "It was a visionary scheme; it had never been done, and had it been practical it would have been done long ago." In reply, I told them something must be done or there would be a large funeral, and I did not want to be one of the mourners. The subject was then more seriously taken up by the company, and it was suggested that a better ore should be secured as a mixture to improve the quality of the iron; but the location of the works was such that a suitable ore could not be got at a price that would permit it to be used as a rail mixture, so this course was abandoned.

The company now began to see that it was necessary that something should be done. The directors called a meeting and, after consultation with some practical iron men, decided to put up a geared two-high mill, and by greatly increasing the speed of the rolls, the rail would be finished in much less time, and consequently at a higher heat, which would prevent the serious trouble of rough and torn flanges. After some pertinent discussion, I was ordered to build a new mill, two-high, geared. As my patience had become exhausted, and being thoroughly disgusted and especially so with the geared mill, I most emphatically said I would not do it, as two of the most objectionable features of the present system would still be retained. I was then asked what right I had to dictate to the company in regard to the policy they should pursue in the line of their business. I answered that I had no right whatever, but that I was thoroughly convinced that it would not remove the difficulty and in the end would be a failure and the result financial disaster. Being a young man and the only capital I had in the world being my reputation, and that being quite limited, I did not purpose placing it in danger where the chances were so unequal. This

interview ended in a suspension of hostilities, and for a short time nothing was said on either side. But the trouble in the mill still continued, and something must be done and quickly. Having already lost my reputation for complaisance and being considered as the most arbitrary of men they had ever met, I consequently concluded that I would do as I had been compelled to do before and many times since—assume authority and go ahead, which I did; and commenced work on the patterns. The drawings had already been practically completed.

After the pattern for the housing was well advanced, Mr. E. Y. Townsend, the Vice-President, came out to the works and I informed him of what I was doing, and again talked the situation over with him. He said nothing, but thought it proper to let the company know what was being done, to which I assented. In about a week, as I remember, he came to the works again. This time he was armed with a legal document opposing the spending of the money in the way it was being done. He handed me the document to read, which I did. I then handed it back to him and said nothing. He then asked me what I thought about it and the best course to pursue. In answer, I said: "You know the troubles we have had, and it is useless to go over them again, and you know my opinion, which is irrevocable." After some friendly talk on the condition and the importance of the change proposed, he said: "Go ahead and build the mill as you want it." I asked: "Do you say that officially?" to which he replied: "I will make it official." And he did so.

When I look back to that eventful interview, which took place on a Sunday morning long years ago, and recall to mind Mr. Townsend and myself, with evidences of failure on all sides, and surrounded by the gloom of future uncertainties, I cannot but feel it was the most critical period not only in my own career, but also in that of the Cambria Iron Company.

And here I wish to say that to Mr. E. Y. Townsend belongs the credit not only of the introduction of the three-high rolls, but also for a large share of the subsequent mar-

vellous prosperity of the Cambria Iron Company, which followed the introduction of the three-high mill and its many accompanying improvements.

The opposition to the three-high mill now came in from all quarters. The heaters on the rail mill were unanimous in their condemnation, and waited on the company to tell them what a direful failure it would be. Next I had to meet the combined prejudice of the ironmasters, who were a power at that time. Some of them would tell the managers that the whole thing was certain to be a failure. Next came my friends, in the trade and out of it, begging me to abandon what would surely prove a failure and blast my reputation for life. One of my dearest friends, with whom I had been employed for a number of years, came to see me and, if possible, to get me to change my plans. To them all I said "No, I can make it work, and it is the only plan that can be adopted that will save the company."

After all these years there is no person other than myself who can fully appreciate the trying position the managers were in. On the one hand, I was to build a mill on an untried plan, and absolutely refusing to build the mill they asked for, knowing full well that only in a small degree would it remedy the trouble, and that the money spent on such a plant would be thrown away. On the other hand, there was a strong party of stockholders, protesting in the most positive manner against going on with my plans, and notifying the managers that they would hold them personally liable for all the loss and damage that might grow out of their unwise action, as they considered this action to be, in adopting a new and untried method that was against all practice in this and the old country, for at that time we were expected to be followers instead of leaders. Notwithstanding all the opposition and trouble we had to encounter, the work on the mill was being pushed along as fast as it was possible. But there were many difficulties in the way. The most serious was the want of proper tools and facilities for doing the work. Many makeshifts had to be improvised, which all required time and labor. During all

this time there was much talk and speculation going on in regard to the final result, to all of which I gave but little attention.

At length the mill was completed, and on the third day of July, 1857, the old mill was shut down for the last time. On the fifth we commenced tearing the old mill out, as the new one had to be put in the same place. The work was pushed as fast as possible, day and night, but, as it was before the days of electric lights, the night work could not be done with the same expedition as to-day. At the same time everything in the rail department was remodelled and the floor line of the mill was raised two feet. On the 29th of the same month everything was completed and the mill ready to start. The starting of the mill was the crucial period.

In giving an account of the starting of the mill, I can probably do no better than quote from a paper written for a former occasion:

There were no invitations sent out. As the heaters to a man were opposed to the new kind of mill, we did not want them about at the start. We, however, secured one of the most reasonable of them to heat the piles for a trial. We had kept the furnace hot for several days as a blind. Everything being ready, we charged six piles. About 10 o'clock in the morning the first pile was drawn out of the furnace and went through the rolls without a hitch, making a perfect rail. You may imagine what my feelings were as I looked upon that first and perfect rail ever made on a three-high train.

And you may know in part how grateful I felt toward the few faithful men who were about me, and who had stood by me during all my trials and difficulties. Among these were Alexander Hamilton, the superintendent of the mill, and Thomas Lapsley, who had charge of the rail department, Wm. Canam and my brother George, all of whom have gone to their reward.

We now proceeded to roll the other five piles. When two more perfect rails had been rolled we were obliged to stop the engine for the reason that we were so intently

watching the rolls that the engine had been neglected, and, being new, the eccentric strap got hot and bent the eccentric rod so much that the engine could no longer be worked. As it would have taken some time to straighten the rod and reset the valves, the remaining piles were hauled out from the furnace onto the mill floor. About this time the heaters, hearing and seeing the exhaust of the engine, came into the mill in a body from the opposite end of the mill to where the rails were. Seeing the unrolled piles lying on the floor, they took it for granted that the new train was a failure; and their remarks about it were far from being complimentary. Mr. Hamilton, coming up and hearing what they were saying about the mill, turned around, and using language more pointed than polite, told them if they would go to the other end of the mill they would see three handsomer rails than had ever been made in their country, Wales. After getting the engine in shape, the day being Friday, we ran all day, and at night put the regular night turn on.

Everything worked well up to noon on Saturday, it being our custom to stop rolling at that time. About six o'clock in the evening Mr. Hamilton and myself left the mill, and on our way home congratulated ourselves on the fact that our long line of troubles and disappointments was now over. About an hour later I heard the fire-alarm whistle blow, and rushing back to the mill, found it one mass of flames from end to end. In less than one hour's time the whole building was burned to the ground, and a story was started that the new mill was a failure, and that we had burned the mill to hide our blundering mistakes. The situation of affairs on that Saturday night was such as might appall the stoutest heart. The product of our labors and anxieties lay there, a mass of black and smoking ruins, and the money that was so hard to get with which to build the mill was gone. The prospect was indeed gloomy, but there was one gleam of light amid all the darkness; and that, the pile of perfect and new rails, which, as Mr. Hamilton had said, had never been beaten in Wales, from which country the greater part of the rails used at that time came. Above

all, the mill had been tried and found to work magnificently, and it was these two facts that gave us all fresh courage, and enabled us to rebuild the mill.

The next day being Sunday, it was devoted to rest and to thinking over the matter. On Monday morning we commenced to clear up the wreck, all the workmen giving a full day towards it, and began the work of rebuilding. In four weeks from that time the mill was running, and made 30,000 tons of rails without a hitch or break of any kind, thus making the Cambria Iron Company a great financial success, and giving them a rail plant far in advance of any other plant in the world. This position they held, unquestioned, both for quality and quantity until the revolutionary invention of Sir Henry Bessemer came into general use.

In the construction of the three-high mill there were many changes and improvements on the old two-high mill. Up to this time the leading spindles had a groove cut in them to weaken them, so that if any extra strain should come on the rolls, they would break instead of the roll; and the couplings were made light so as to act as a kind of a safety-valve. Then there was a breaking box placed between the screw and the roll. If there was not one of these safety devices breaking each day, the pattern was made lighter. The result was that some of them were breaking several times daily, furnishing a constant source of annoyance. In building the new mill they were all made so strong that they were not calculated to break. The breaking box on top of the roll was made solid, as they were apt, when they gave way, to break the collars on the rolls, which should, if possible, be avoided. All these changes were stoutly opposed by the foremen and workmen of the mill. A few days before the mill was ready to start, the superintendent of the mill discovered that the breaking box was solid; he then got the pattern and took it to Mr. Lewis, the pattern-maker, and told him there was a mistake, that it was made solid. Mr. Lewis told him that it was made as the old man had ordered it, to which the superintendent said, "the old man has gone crazy." He looked me up and wanted to know if I had ordered the breaking box for the

new train solid. I said, "yes;" he replied that if with solid spindles, heavy coupling boxes and solid breaking boxes on top of the rolls, a piece should enter a wrong groove, or a collar should form on the rolls, which was sure to take place, the mill would be broken to pieces; to which I replied: "I would rather have a grand old smash-up once in a while than be continually breaking something and keeping the mill standing half the time and the metal wasting in the furnace." He said: "Well, you will get it, sure;" but we did not, and, as before stated, the mill made 30,000 tons of rails without a break of any kind, which, at that time, on iron, was nearly a year's work.

The heating furnaces were rebuilt, making them larger, the roofs much higher, and the length of the furnace greatly increased, which about doubled the work that had previously been done. There were also a number of improvements made on the train to facilitate the work, and make it much easier for the men. Among them was the introduction of the driven feed-roller, out of which, later on, came the blooming table, which is now indispensable in the rolling of steel ingots either on a three-high or reversing mill.

In 1864 the Bessemer process was introduced in this country. Its introduction and perfection will ever remain one of the most interesting epochs in the history of the iron business.

As already stated, the forge carpenter and millwright were superseded by the machinist. Immediately after the introduction of the three-high mill all the rail mills in the country were changed, and all the new ones that were built adopted the same plan. In fact, as Mr. B. F. Jones, one of the oldest, one of the leading and one of the most practical and successful ironmasters in the country, and one of the very first to see the advantages of the system, said to me a short time since, it was the commencement of the great improvement which took place in the iron works after 1857 which paved the way for the introduction of the phenomenal "Bessemer" process, which, as the Hon. Abram S. Hewitt says, takes its rank with the great events which have changed the face of society since the time of the Middle Ages.

At this time the machinists before alluded to were called to the front to brave the danger and fight the great battles that have ever to be encountered in the introduction of new metallurgical processes, and in none were the difficulties more alarming and disheartening than in the Bessemer process. These men had now received a training which eminently fitted them for the duties they were called upon to perform. Having been inured to hard work, they entered into this new field with such an amount of energy and determination that it made failure impossible.

In witnessing the beautiful and interesting but simple process of blowing a heat of metal, and the regularity with which it is done at this time, and the quantity turned out, it is impossible for one wholly unacquainted with its early history to even in a measure realize the fear and anxiety of those who were responsible for the result. When a charge of metal was poured into the vessel our anxiety commenced, and as the heat increased, our anxiety increased in a corresponding ratio, until both became intense. It was when the heat was greatest that accidents were most likely to happen. The refractory material with which the converters were lined, especially the bottoms, would become plastic, and when in that condition the effect of the heat and the blast would waste the tuyeres and bottoms away so rapidly that from one to three heats were all we could get off of one bottom. Frequently they would give out at the first heat, then out would come the metal through the bottom; and having to use much water about the converter, the place under the vessel was at all times wet, and the result was explosions, often very dangerous, as the hot metal was blown in all directions, frequently inflicting serious injuries on the workmen, a calamity greatly dreaded and the cause of the gravest anxiety to those in charge. When an accident would occur anywhere about the works the first question asked would be: "Is any one hurt?" If not we would go to work at once to repair with that object only in mind. If, on the contrary, some of the workmen were killed or seriously injured, it was impossible to describe the distress of mind that the person in charge had to endure. The anxiety

one had when the charge was put in the vessel was increased with the heat until the heat was blown; but it did not end with the blowing of the heat. When the vessel was turned down it sometimes went too far and some of the metal ran out, resulting frequently in a grand pyrotechnic display of an exceedingly dangerous character. The next operation was to get the metal in the ladle, which was generally not a very difficult one, but it would frequently burn through the ladle, and then the only thing that could be done was to let it run into the pit and order all hands out of the way, for fear of an explosion. As soon as the metal was set all hands commenced to clean the pit, which was no easy task. Here were eight tons of molten steel in the pit burned fast to ingot moulds, bottom and sides of the pit, and to everything that would not burn up. If we were so fortunate as to get the ladle over the pit in good shape our anxiety was not yet at an end. It quite frequently happened that the stopper would pull off the end of the rod; then we had to use what we called a pricker to open the nozzle from the bottom. If the metal happened to be cold, which at that time it was apt to be, the nozzle would freeze up, as we called it; then the metal would have to be poured out of the top of the ladle into the mould, cinder and steel all together, with the result that generally the most of it got into the pit; then, again, if we escaped an explosion we still had a mess in the pit. Altogether the difficulties we encountered were enough to appall the bravest hearts. My brother George once said, when at Cambria, that he did not believe there was a man who ever went into the Bessemer business, and was responsible for the result, who did not at times wish he had never gone into it; and so far as my experience goes I can fully verify it. And, further, I think that, if it had not been for the interesting and exciting character of the business, but few men would have been willing to endure the trouble and anxiety and to endure the physical labor and danger to which he and the workmen were constantly exposed long enough to have placed the business on a commercial basis.

Having alluded to the trouble we had with the converter

tuyeres which caused so much anxiety and loss of time, I will now explain how we got over the difficulty at once. We were only getting from two to four heats off of a bottom and then would have to turn the vessel down and put in tuyeres during the blow. It so happened that, at a time when we were having more than the usual trouble, the vessel was turned down and we were putting in two tuyeres when I was sent for, to go to the blast furnace, there being trouble there. As soon as the vessel was turned up I started for the furnace, not in the serenest state of mind; on the way over I was thinking over some new device for making the bottoms so that they could be burned in order to make them harder and better able to resist the action of the blast, as I had been thinking that that was one of the troubles. As I went into the furnace I noticed some firebricks about 5 inches square and 16 inches in length, such as are used in blast-furnace lining. At once I ordered some of them sent over to the converting department, and as soon as I could I went over and had one of them placed on end in the bottom between the tuyeres and well rammed in with ganister, put in the oven and well dried and put in the vessel. Result: Twelve heats off of one bottom.

From this time our troubles began to diminish, and instead of making ten and twelve heats per day we soon ran up to fifty and sixty heats in twelve hours, and some of the works are now making seventy and eighty. This system of making bottoms was at once generally adopted, and is still in use.

I shall now return to the rolling mill. As already stated, with the introduction of the three-high mill in 1857, the commencement of the great improvement in rolling mills and machinery connected with them took place. The rolls were made larger in diameter, better fitted up, and a more powerful and a much better class of engines was introduced, larger and better heating furnaces were built, and many labor-saving devices were introduced. But with the marvellously increased production of Bessemer steel it was evident that a larger ingot must be used in order to prevent congestion in the pit furnaces and rolls. This, of course,

involved the building of larger, heavier and more rapid working machinery.

In 1868 the lamented Holley, who later on became the consulting engineer of the Bessemer works and so remained until his death, and to whom the country is largely indebted for the introduction of the Bessemer process and for many improvements and important suggestions in the art, built a three-high blooming mill at Troy, N. Y. This mill had the top and bottom rolls stationary, the middle roll being moved up and down, to suit the work, by four screws passing through the bearing carrying the rolls. In the bearing there was a thread corresponding to the thread on the screws, which screws were driven by power. He also had lifting tables, front and back, fitted with loose rolls, and the ingots were pushed into the rolls by hand both in front and in back.

In 1871 my brother George, then superintendent of the Cambria Works, built a three-high blooming mill in which the middle roll was stationary and the top and bottom ones movable, with feed tables both front and back, and the rollers driven by power taken from the train. He also introduced what is called a "pusher" to adjust the ingot in a proper position on the table and also an arrangement for moving the ingot on the table in proper position to enter the rolls.

In 1872 we built at Bethlehem, Pa., a three-high mill in which all the rolls were fixed, with tables similar to those at Cambria, but driven by an independent power which very much simplified the arrangement of driving the tables. This is the plan of mill that was generally adopted, and for a moderate sized ingot and quick working is probably the best plan of mill. But for heavy ingots and for variety of work the reversing mills are preferable.

The rail trains are, with two exceptions, three-high, with larger rolls, very heavy housings and fittings, and more powerful engines, and generally have some kind of labor-saving device attached to the rolls. In fact all the modern rail mills have introduced labor-saving machinery to such an extent that there is, comparatively speaking, but

little left for man to do. This is to a great extent due to the introduction of steel, as it rarely either splits or cracks in rolling, while iron is ever liable to do both, which renders the use of delicate automatic machinery more difficult in rolling iron than in rolling steel.

Many instructive, interesting, annoying and amusing incidents which might be related occurred in connection with the almost magical developments which took place in the manufacture of iron and steel during my long association with the business. But time will not permit.

We left the blast furnaces in 1840, which, as before mentioned, was the commencement of the use of mineral coal, from which period the greatly increased production commenced. While there was no practical change in the principle of making pig iron, yet, the continued increase in size of the furnace, the increased pressure and quantity of blast, the introduction of the Whitwell system of fire-brick stoves, the better understanding of furnace working, the increased knowledge of the chemistry of pig-iron making—all these, coupled with the indefatigable determination of the men in charge, have contributed to bring about the unprecedented and phenomenal production which has so amazed the iron makers of the world.

In 1868 the manufacture of acid open-hearth steel commenced; but its progress was slow, and following the Bessemer, this process not being so interesting and exciting, did not command the attention and respect to which it was entitled. The fact that the Bessemer was in the lead and the machinery was already in use, and that the knowledge of refractory material and in the handling of the steel was acquired, made the introduction of the open-hearth process easy compared to the Bessemer. But the fact that it quietly made its way into general use does not in any way detract from its great usefulness, and, with the invention and introduction of the "Thomas" basic process and its application to the Siemens-Martin open-hearth system, it takes rank only second to Bessemer as one of the greatest metallurgical inventions of the age. And taking into consideration the character of our ores and coal, and their geographical location, the supe-

riority of the metal produced by this process, for structural and machine purposes, may cause it in the near future to outrank the Bessemer in value and general usefulness.

When we look back to the commencement of the last half of the present century, and take a thoughtful survey of all the inventions and improvements that have taken place in the arts of metallurgy during this period, the complete reversal of the position that iron and steel formerly held in relation to each other, the superiority of steel over iron in the useful arts, and the immensely increased production which is unparalleled in the history of metallurgy, it seems impossible to fully realize that so great a change could have taken place within so brief a time.

While we have properly received great credit for the unprecedented developments we have made in the iron and steel industry in the United States, we must not forget that it was the inventions of Cort, of Mushet, of Bessemer, of Siemens, and of Thomas that enabled us to accomplish such important results; and to them all civilized nations owe a debt of gratitude for the incomparable blessing their inventions have conferred on society.

Yet how few of us even for a moment think of the trials, troubles, disappointments, mental anxiety and bodily toil these men had to undergo in the perfection and introduction of their inventions, besides suffering the sneers and jibes of those who imagine that an inventor is nothing but a wild enthusiast, and treat him accordingly. The story of many inventors is truly pathetic and none more so than that of the lamented Thomas. The personal side of the story of the inventor of the basic process can only be appreciated by the reading of his life.

It should not be forgotten that England is the birthplace and home of the "Iron and Steel Institute," and much of our success is due to the information we have gained from the invaluable papers read at their meetings and the discussions that followed them. Here I wish to say that I would commit an act of ingratitude should I fail to give credit to the brave and noble workmen who, throughout my long connection with the business, have ever stood ready to

meet any emergency, no matter what the danger or difficulty might be. All that needed to be said was, "Come, boys," but never "Go, boys," and if the difficulties were not insurmountable they were sure to be overcome; and too much credit cannot be given to these fearless and energetic men for the almost fabulous progress that has been made in the manufacture of iron and steel in this country.

Having already intimated that the United States was not the original home of the iron and steel industry, I will again refer to it.

When I look back to my early days in the iron business long, long ago, probably too long, it brings to mind one of the happiest periods of my life. After my daily labor was done I was free from all care until the next morning. After supper, at half-past six, then a simple meal, I returned to the works and helped the puddler, heater or roller, as the case might be, until about 10 o'clock. At that time the practical men, puddlers, heaters and rollers, were generally Englishmen and Welshmen. After the heats were charged in the furnaces, and while waiting for the charges to become heated, they would get their pipe—"cutty" they called it—and sit down on a pile of pig or puddled iron, as happened to be most convenient, and take their smoke. Having gained their confidence, I would take a seat by them and then they would tell me about the works in England and describe how their mills were arranged, their system of rolling, the principle and construction of their puddling and heating furnaces, and how to work them. As I spent my nights in assisting them to puddle, heat and roll, I gained a very general practical knowledge of the manufacture of wrought iron, which soon became of great value to me; and to the nights spent in the works with these hearty and generous workmen I owe much of whatever success I may have attained in after life. For the kind and generous manner in which I was always treated by them they ever have a green spot in my memory. In comparing this happy period of my life with what I have since many times gone through, it might, with propriety, be compared with the "Elysian Fields."

How little do the younger men that now have charge of our great iron and steel industries know or even think of the severe mental strain, the great amount of bodily toil, the vexation, the surprises, and the disappointments that had to be endured by the men in charge during the erection and perfection of these vast establishments that are now engaged in the manufacture of iron and steel. And, gentlemen, let me here say that this great work was not accomplished by command but by example. It was the men in training, before alluded to, who erected, perfected and put in operation these most marvellous enterprises of the age. And to these noble, brave and energetic men the people of this country owe a debt of gratitude for the far-reaching results they so thoroughly accomplished, and which have already changed the social condition of our vast territory. They have furnished us with a material which for quality and cheapness and the quantity furnished in a given time is without parallel, and could not have been realized by any other known methods. Without it the building of trans-continental roads would have been almost impossible. Had the rails been made in the old way out of the puddled iron, with the increased traffic on the Atlantic ends of the lines, they would be worn out before the Pacific coast could have been reached. The credit does not end here. The reduction of freight rates, owing to the general use of steel rails, is so enormous that it has been intimated by one of our most distinguished public men that the saving alone on the cost of transportation due to the use of steel in the place of iron would, if available, amount to a sum sufficient to pay our national debt in a comparatively short time.

In addition to the use of steel for rails, the Great West is being fenced with steel at a cost that seems almost fabulously cheap, and this product is being used largely for many other purposes. It was formerly iron that was used for structural work, now it is steel; and it has practically superseded the use of wrought iron. Steel is largely used in the construction of all grades of machinery employed in the manufacturing arts. It is the base of our immense in-

land system of transportation. It is this imperial metal that has enabled the engineer to perform the daring and remarkable engineering feats which he has accomplished during the last half of the century, without which they would have been practically impossible. It is the material used in the construction of these monster floating palaces that cross the vast ocean with the regularity of a railroad train.

Fifty years ago steel was a luxury to the engineer. Modern practice of steel-making in the hands of the mechanical engineer, the metallurgist and the chemist has wrought wonders in producing a material which is used alike in the manufacture of articles of the most weighty, the rudest and cheapest grades, and in the construction of the most intricate, the finest and most delicate implements and machinery. And it is boldly asserting its value and importance through every walk of life.

It is to the invention, introduction and perfection of the modern system of steel-making in this country that we are indebted for the education of our people in the scientific, mechanical and metallurgical arts, which has enabled them to erect such manufacturing plants as were necessary to supply our Government with the sinews of war, which made it possible to achieve those glorious victories which at once placed us in the front rank among the nations of the earth.

I will conclude these reminiscences by giving some statistics compiled by the American Iron and Steel Association, which show the wonderful progress that our iron and steel industries have made since 1840, when I started out to learn my trade as a blacksmith and machinist.

PRODUCTION OF ALL KINDS OF CRUDE STEEL IN THE UNITED STATES.

	Bessemer Ingots. Gross Tons.	Open Hearth Ingots. Gross Tons.	All Other Steel. Gross Tons.	Total Gross Tons.
1867	2,679	0	16,964	19,643
1895	4,909,128	1,137,182	68,524	6,114,834

PRODUCTION OF PIG IRON IN THE UNITED STATES.

	Gross Tons.
1840	286,903
1890	9,202,703
Estimated production for 1899	13,500,000

UNITED STATES.

Production of Pig Iron.—The total production of pig iron in the United States in the past eighty-six years is shown in the following table:

TOTAL PRODUCTION OF PIG IRON IN THE UNITED STATES FROM 1810 to 1898.

Year.	Long Tons.	Year.	Long Tons.
1810	53,908	1874	2,401,362
1820	20,000	1875	2,023,733
1830	165,000	1876	1,868,961
1840	286,903	1877	2,066,594
1850	563,755	1878	2,301,215
1854	657,337	1879	2,741,853
1855	700,159	1880	3,835,191
1856	788,515	1881	4,144,254
1857	712,640	1882	4,623,323
1858	629,548	1883	4,595,510
1859	750,560	1884	4,097,868
1860	821,923	1885	4,044,526
1861	653,164	1886	5,683,329
1862	703,270	1887	6,417,148
1863	846,075	1888	6,489,738
1864	1,014,282	1889	7,603,642
1865	831,770	1890	9,202,703
1866	1,205,663	1891	8,279,870
1867	1,365,823	1892	9,157,000
1868	1,431,250	1893	7,124,502
1869	1,711,287	1894	6,657,388
1870	1,665,179	1895	9,446,308
1871	1,706,793	1896	8,623,127
1872	2,548,713	1897	9,652,680
1873	2,560,963	1898	11,773,934

PRODUCTION OF PIG IRON, STEEL INGOTS AND CASTINGS, AND FINISHED IRON AND STEEL IN THE UNITED STATES FROM 1890 TO 1898 INCLUSIVE.

Years.	Pig Iron. Gross Tons.	Bessemer Steel Ingots and Castings. Gross Tons.	Open Hearth Steel Ingots and Castings. Gross Tons.	Total Steel. Ingots and Castings, Including Crucible. Gross Tons.	Finished Rolled Iron and Steel. All Kinds. Gross Tons.
1890	9,202,703	3,688,871	513,232	4,277,071	6,022,875
1891	8,279,870	3,247,417	579,733	3,904,240	5,390,963
1892	9,157,000	4,168,435	669,889	4,927,581	6,165,814
1893	7,124,502	3,215,686	737,890	4,919,995	4,975,685
1894	6,657,388	3,571,313	784,936	4,412,032	4,642,211
1895	9,446,308	4,909,128	1,137,182	6,114,834	6,189,574
1896	8,623,127	3,919,906	1,298,700	5,281,689	5,515,841
1897	9,652,680	5,475,315	1,608,671	7,156,957	7,001,728
1898	11,773,934	6,609,017	2,230,992	8,932,857	8,513,370

Mechanical and Engineering Section.

Stated Meeting, held Thursday, November 9, 1899.

THE PRESSING OF STEEL; WITH ESPECIAL REFERENCE TO ECONOMY IN TRANSPORTATION.

BY HENRIK V. LOSS, M.E.

I. THE FLOW OF STEEL.

It is an ever-true maxim in life and one possessing a special importance in the line of engineering that the only successful methods to be adopted are those that produce the best results with the least expenditure of time and money. From the dawn of history, the examination of implements indicates that, while being both rough and crude, as the necessary result of an undeveloped state of the individual, as well as of the community, their purposes, as indicated by form and material, show, nevertheless, the analytic workings of a mind bent upon producing the best results from the least amount of labor.

The history of our profession is, of course, the history of the world; and the battles incident to the inflexible laws

of evolution, followed by the old, old story of the "survival of the fittest," have both made the above maxim a law, the non-compliance with which carries with it as a penalty absolute failure.

To produce a certain mechanical result means to accomplish a certain amount of work, and, leaving finance out of consideration, two ways are open to effect this end: the exerting of a larger force throughout a shorter space, and a smaller force throughout a greater space.

But, in the course of the industrial competition, the demands upon our profession became greater and greater, calling for the completion of powerful results inside of shorter and still shorter time. This again meant machines which all had to be quick in action and capable of exerting intense pressures. In the design of motors and machines, simplicity of detail and a small number of parts have always been aims of first importance; because, aside from the fact that such meant less first cost and less repairs, the frictional resistances might otherwise at times become so great as to leave the machine absolutely unable to perform the task assigned to it. And it was this call for the quick exertion of large powers, coupled with the desire to reduce all frictional resistances to a minimum, and also, no doubt, to have a machine that should be under the complete control of the operator—all of which, I say, gave birth to the hydraulic press.

I am not here to give you a history of hydraulic engineering, as my subject is the *work*, rather than the *machine* by which the work is done. It is quite safe to assert that the vast majority of heavy hydraulic machines hitherto built have been used in connection with processes, the main characteristics of which involve the flow of metals, and it is inside of this field that I shall bring to your attention a series of experiments which I have carried on at intermittent periods for the last six to seven years.

In pressing steel the operation can be divided into three distinct systems, each one representing separate lines of resistance to the yielding of the material, namely:

(1) When the material to be treated is absolutely free to

flow in any direction, being nowise confined in any die-chamber, as in shearing.

(2) When the material to be treated is partly free and partly confined, as in punching.

(3) When the material to be treated is wholly confined in dies, as when upsetting rounds and squares, or bridge eye-bars; also as when flanging and riveting.

In order to acquire the most possible complete information as to the strains and stresses existing during the different stages of the pressing process, a diagram showing graphically the rising or falling in resistance of the metal will naturally give the most general satisfaction. To rely upon gauges is placing a dangerous confidence when using high pressures, as the water hammer—which always exists to a greater or smaller degree—will quickly ruin them. Besides, a gauge would have to be used in connection with some other additional instrument controlling the stroke of the press, if a complete record is to be secured. Due to these conditions, I have, therefore, adopted in all my experiments the application of a hydraulic reducing cylinder, the small area of which is connected as close as possible to the main operating ram, while to the greater area is connected an ordinary steam indicator. The larger area, as well as the indicator cylinder, have, previous to each experiment, been filled with water, and a connection has been accomplished between the moving dies and the indicator drum. The result is a card, the ordinates of which represent the hydraulic pressure in pounds per square inch to the extent of their lengths in inches, multiplied by the product of the spring number and ratio of reduction in reducing cylinder. The above device is illustrated by *Fig. 1*.

We shall now consider the resistances to the first mode of flow.

The experiments in this field cover an extended series of indicator cards of the shearing of hot as well as of cold material. The hot work represented dimensions varying from 4 x 4 inches to about 10 x 10 inches. The cold work extended over rectangular bars of widths from 4 to 8 inches, and thicknesses of from $\frac{3}{4}$ to $2\frac{1}{2}$ inches. The latter also included

angles of iron and steel of ordinary merchantable sizes. I desire to say in this place that, in dealing with these different experiments, I do not now have the time, nor is it the purpose of the present paper, to give anything like a complete essay of all the detailed results derived, because the

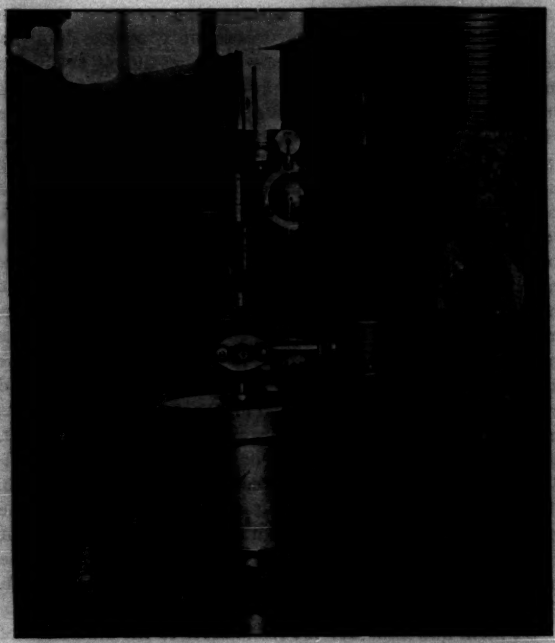


FIG. 1.

indicator cards on each field represent such volumes of interesting information that separate papers can be written on the resistances characteristic to each system. It *is* the purpose, however, to give somewhat of a general view with reference to such figures and pressures that each system de-

veloped, and which might illustrate the duties of the pressing machinery, which the mechanical engineer, in this special branch, may be called upon to design. *Fig. 2* represents typical cards of the shearing of a hot bar. It is seen how the resistances are gradually increasing, finally reaching a maximum at an early stage, and, while afterwards decreasing, are, nevertheless, existing throughout the entire stroke, that is, up to the time the knife has penetrated the entire thickness of the bloom. Both knives were flat, with no back clearance.

The maximum resistance increases as the temperature is lowered, as shown by the different heights and areas of each succeeding card, all having been taken one after the other from the same ingot, as it came from the blooming rolls.

The general results, as far as actual figures are concerned, can be summed up as follows:

Resistance per square inch varies from about 5,000 pounds for a 9 x 9-inch bloom to about 9,000 pounds for a 6 x 6-inch, and reaching about 11,000 pounds for 4 x 6½-inch, which figures all represent steel of about ·20 per cent. carbon, 70,000 pounds ultimate, and at such temperatures which the bloom generally possesses when first reaching the rolls, say about 2,500° F. As it passes through the mill, the bloom gradually cools, and, as the last billet is cut, the temperature is considerably decreased, say possibly down to about 1,800°, and is having its resistance correspondingly increased at a rate of about 50 per cent. for the larger bloom and 100 per cent. for the lesser one.

The energy in foot-pounds at the first cuts varies from 540 for the 9 x 9-inch bloom to 800 for the smaller one, which figures are increased with the decreasing temperature at a rate of about 40 per cent. for the larger dimensions and 75 to 80 per cent. for the smaller ones.

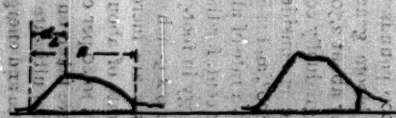
Cards were taken on spring steel with 1 per cent. carbon, possessing an ultimate of 130,000 pounds per square inch. Its resistance and energy when compared to the ·20 per cent. steel were increased about 25 and 14 per cent. respectively.

The local irregularities on these cards are due to the fact

No. 1. No. 2. No. 3.

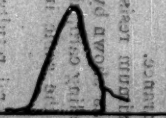
FIG. 2.—6 x 6-inch structural steel.

Maximum ultimate pressure per square inch.			Foot-pounds per square inch of bloom.		
No. 1.	No. 2.	No. 3.	No. 1.	No. 2.	No. 3.
9,000 lbs.	10,400 lbs.	11,000 lbs.	800	840	940

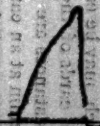


8° bevel, iron. 1⅛ inches thick.

8° bevel, steel. 1¼ inches thick.



4° bevel, steel. 1¼ inches thick.



Flat knives, steel. 1¼ inches thick.

FIG. 3.—Types of cards.

Scale: Horizontal dimensions = full size and 1 inch vertical = 350,000 pounds.

that the hydraulic shear upon which the experiments were made was driven directly by a duplex pump (without accumulator), and the want of uniformity in flow of water from a pump of this kind was naturally transmitted to the indicator needle in the manner as shown graphically.

Fig. 3 represents typical cards of the shearing of a cold bar, and the general outline of such a card will not vary with the form and shape of the bar to be severed. This will be seen shortly, when a card from a steel or iron angle will be thrown upon the screen. The first of the above figures represents an iron bar 5 x 1¼ inches, the second a steel bar 5 x 1¼ inches, both of these two being cut by a knife with an angle of 8°. The third card was taken from a steel bar 5 x 1¼ inches, with an angle of knife of 4°, while the last of all was taken with a flat knife on a 5 x 1¼-inch bar. The pressure rose quicker than with hot work, and, the flatter the knife, the earlier in the stroke was the maximum resistance reached. This maximum did also occur at a somewhat later period with an iron than with a steel section, showing in the former a greater distribution throughout the stroke of cutting. It is only fair to assume that this latter feature will be equally in evidence when comparing soft steel to a high-tension material. With flat knives the card becomes very short, indicating, generally, so violent a rupture as to make the needle vibrate quite considerably. The average results on rectangular bars as to actual figures can be summed up as follows:

Necessary pressure per square inch of section to shear a cold bar made from 70,000 pounds steel, and with flat knives, equals about 48,000 pounds.

For an angle of 4° of knife blade the pressure per square inch increases from 36,000 pounds for bars of 1 inch thickness up to 45,000 pounds for 2 inches of thickness.

Within the same limits of thicknesses with 8° blades, the power necessary would vary from about 22,000 to 32,000 pounds per square inch.

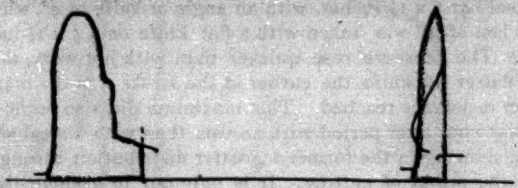
Energy per square inch consumed in cutting rectangular steel bars is as follows:

FOR 1 INCH THICK BARS.

700 inch-pounds for 8° bevel.
1,000 " " " 4° "
1,200 " " " flat knives.

For 2 inches thick bars, the above figures have risen to 1,600-, 2,000- and 2,500-pound inches, respectively.

Fig. 4 represents types of cards of angles, in both cases using flat knives, the first one being taken from a 6 x 6 inches by ¾-inch iron angle, and the second from a steel angle, with dimensions of 6 x 6 inches by ½ inch. The same general characteristics are seen to exist here as with the rectangular bars. The average results in figures for cutting iron and steel angles can be placed as follows:



6 x 6 x ¾ inches iron angle. 6 x 6 x ½ inches steel angle.

FIG. 4.—Pressure diagram for iron and steel angles.

The necessary power to cut a steel angle with dimensions of legs, a and b, and with a thickness t is:

$$P = \tfrac{1}{2} f (a + b) \sqrt{t^3}$$

where f is the ultimate per square inch.

The energy per square inch in foot-pounds can be written in the same manner:

$$E = 1600 (a + b) t^2$$

where the letters denote the same as above.

A cold bar, rectangular or otherwise, when exposed to ordinary shearing machinery, as this exists in actual practice, is broken off, and not sheared off. The knife compresses the surface metal, causing the driving force to be distributed on a small area, with a center of pressure located at a small distance away from the line of final rupture.

This distance represents the leverage of the above-mentioned force, and the product equals the resulting bending moment, tending to sever the bar. A large number of experiments were made with the view of determining the position of this center of pressure, and it was found to depend upon the thickness of the bar. Illustrating the above fact, the formula for the flat knife, as worked up on this basis, is represented by:

$$P = \tfrac{2}{3}\, w\, t\, f$$

where P equals total shearing pressure, t and w the thickness and width of bar, respectively, while f equals the ultimate resistance of the material per square inch for flexure. This formula will be found to give good results.

Summing up the general characteristics of the indicator cards, as taken by and derived from the system of pressing metal without any restricting dies whatever, we find the resistances to rise quickly and reach a maximum at an early period, which point being reached, a more or less gradual decrease takes place until rupture occurs. The metal itself will mainly flow in the direction of the pressure, having little or no side flow, while the point of rupture for cold work is always reached before the entire thickness has been penetrated. This point of the stroke, when measured in inches from the time the knife comes in contact with the bar, is represented by the formula:

$$s = \tfrac{1}{3}\,(t\sqrt{t^2} + w\ tang\ a)$$

where t and w equal thickness and width of bar and a represents angle of knife in degrees.

THE SECOND SYSTEM.

It has often been asserted that punching is nothing more or less than a case of shearing with flat knives. That this is erroneous will shortly be seen when a typical punching card is thrown upon the screen. In shearing, let it be remembered that the flow is absolutely unrestricted by any dies, while with punching the metal surrounding the finished hole acts during the operation, by its resistance to flow, partly as the walls of a die-chamber.

In cold shearing the rupture occurs when the bending moment on the bar reaches the resisting moment of the section; while in the case of punching is witnessed the phenomena of a detailed yield of the molecules—the whole process of penetrating through any one thickness being divided, as it were, into periods: the first one representing the resistance to rupture of a certain portion of the thickness, this to be succeeded by a following one where the resistance has become still greater—the line of resistance

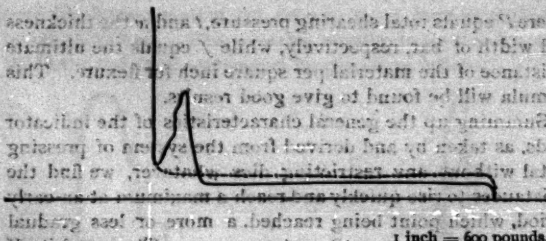

1 inch = 600 pounds.
Cold punching.
¼-inch steel.
Six ¹¹⁄₁₆-inch holes.
No lead.
Reduction = 1:0·37.
Σ = 11,200 foot-pounds.
Σ = 1,300 foot-pounds per square inch of section.
Pressure to lift dies = 75 pounds.
Maximum pressure to punch = 440 pounds.
Maximum pressure to punch = 35,000 pounds per square inch of material.

FIG. 5.

continuously rising until the maximum is passed, after which it very quickly decreases—in quite marked contrast to what exists during the process of shearing, where, as seen by the cards, the heavier resistances are maintained during longer periods, causing diagrams less pointed but more rectangular.

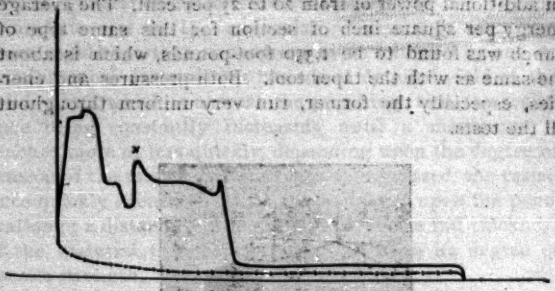
Fig. 5 represents a card taken during the operation of punching six ¹¹⁄₁₆-inch holes through ¼-inch steel, all tools being square to their axes, and all meeting the plate simultaneously.

When it is desired to punch a very large number of holes the tools are divided up into series, each series being

then set a little in advance of the following one, so as to make the pressure more uniform throughout the entire stroke.

A typical card of this kind is given by *Fig. 6*, which represents the operation of punching two holes, each being 22½ inches long by 5 inches wide, as also twenty-three 1¼-inch holes, all through ⅞-inch steel.

The results from a large number of cards on ½-inch, ⅞-inch and 1-inch materials are as follows:



Reduction = 2·565 : 1.
Σ = 88,000 foot-pounds.
Σ = 1,190 foot-pounds per square inch of severed section for combined shear and punching.

1 inch equals 600 pounds.
Cold punching.
⅞-inch steel.
Two holes, 22½ x 5 inches and twenty-three 1¼-inch holes.
B. & O. cross transoms.

Pressure to lift dies = 75 pounds per square inch.
Pressure at × to finish punching 22½ x 5-inch holes = 490 pounds.
Maximum pressure to punch = 712 pounds per square inch.
1 in 10
Shear on punch.

FIG. 6.

Pressure per square inch to punch 70,000 to 75,000 pounds steel varies from 30,000 pounds to 38,000 pounds, depending upon the condition of the punches.

Average energy per square inch of severed surfaces = about 1,495 foot-pounds, the extremes varying about 10 per cent. each side of this figure.

It must be noted that all the punches were provided

with some shear, as illustrated by *Fig.* 7, which shows the two styles of tools mostly in use. The figures as already given refer to the long punch, the end of which has a shear of $\frac{1}{32}$ inch to the inch on each side of center.

I also made some experiments with the smaller one, which, by-the-by, is *not* the tool generally adopted at our work—and the results with new punches were 38,500 pounds per square inch of section to penetrate the plate. When compared to the former type this is seen to represent an additional power of from 20 to 25 per cent. The average energy per square inch of section for this same type of punch was found to be 1,350 foot-pounds, which is about the same as with the taper tool. Both pressures and energies, especially the former, run very uniform throughout all the tests.

FIG. 7.

The peculiar shape, as exhibited by an ordinary punching, shows plainly the existence of a detailed yield, possessing, in fact, the appearance as if the punch had penetrated two separate plates, originally placed one above the other.

Quite a number of experiments on simple punching (and limited to $\frac{1}{2}$-inch holes and less) were made some years ago by the late Mr. Alfred E. Hunt, of Pittsburg, and a paper on

same was subsequently read before the American Society of Civil Engineers, at their World's Fair meeting in 1893. In comparing notes I find that the energies given in his paper—especially for the greater thicknesses—follow closely the data given above. His pressures per square inch of metal severed run up to those generally assumed for shearing, as he accepts both processes as identical. They are thus about from 50 to 60 per cent. in excess of the results of my own investigations.

The general characteristics of this system are a quick, immediate rise in the molecular resistance in a manner more rapid than that of shearing to be followed by one or possibly more intermittent periods of detailed yield of the solid strata which is nearest the punching tool, the resistance being constantly increasing until a maximum is reached more or less quickly, depending upon the degree of tension of the material. This point being passed, the resistance quickly decreases until rupture occurs upon the penetration of a distance more or less equal to the full thickness of the material, this depending again upon its degree of tensile strength.

[*To be concluded.*]

NOTES AND COMMENTS.

ELECTROPLATED STEAMSHIPS.

The Navy Department has received a full report showing the record of the American steam tug "Assistance," which for four years has been used as an experiment in electroplating with copper as a method of protecting iron ships' bottoms. The iron plates of this vessel were covered by a thin copper coating applied by means of electricity. The "Assistance," after being electroplated, was launched in Jersey City on February 22, 1895, and from that time until a few days ago, she was constantly in the water, and no attempt was made to clean her bottom. Upon being hauled out of the water at the Norfolk Navy Yard the craft was found to be remarkably clean. The bottom was entirely free from barnacles or marine growth of any kind. For the year just past she has been towing in the lower waters of the Chesapeake, and while other tug boats made it a practice to haul out to clean bottoms every four weeks the "Assistance" remained constantly at work.

As a result of the successful outcome of the "Assistance" test it is thought to be quite probable that the Navy Department will order the electroplating

of the bottoms of the new war-ships now building. The electroplating process can be carried out on the plates before they are fitted to the frames. In this process the copper is, figuratively speaking, fused into the steel plates to a depth of about $\frac{1}{32}$ of an inch. The time required to treat a plate is about forty-eight hours.

The cost of applying the copper in this manner is said to be about $3 per square foot. The cost of the method of sheathing now commonly used is about $5 per square foot. By sheathing is meant the English system of planking the outer skin of an iron or steel vessel, countersinking the boltheads, and then fastening copper plates to the wooden planking after the manner followed on wooden ships. If the copper plates were applied directly to the skin of an iron or steel vessel galvanic action would result, hence the necessity of the interlayer of wood. The disadvantages attending sheathing are the increased weight of hull and the disturbance of a vessel's speed lines.

For a vessel 250 feet long there would be required about 35 tons of copper, by the electric process. If covered by the old style sheathing of wood and copper the added weight is more than 100 tons. It has even been found that the use of wooden sheathing between the iron plating and the copper sheathing forms a galvanic pile, as the wood in time becomes water-logged, thus establishing a current between the copper and the iron.

If the process develops no unexpected drawbacks, the value of this comparatively simple method of overcoming one of the most serious difficulties in iron and steel vessels, can hardly be overestimated. It is claimed that as much as $20,000 is yearly expended by various ships in the transatlantic trade as the result of overcoming the added friction caused by fouling. To dock one of the big ships of several well-known lines only twice a year, at $7,500, would bring the total loss per craft up to $35,000 as a yearly penalty for unprotected bottoms. The frictional contact of water against copper is considerably less than against iron, as a painted surface can never be made as smooth as a burnished copper surface. An iron vessel with a speed of twenty knots per hour, if coated with copper, would have, it is calculated, a speed of twenty-one knots per hour.

PRINTING BY X-RAYS.

Dr. Frederick Strange Kolle, in a late number of *The Electrical Engineer*, publishes a description of the "new process of printing by the use of X-rays," which opens up what he claims to be a feasible method of producing an immense number of impressions or records. Dr. Kolle states that printing by the use of X-rays was, perhaps, first suggested by an article by Elihu Thomson in 1896, wherein he showed that multiple radiographs had been made at one exposure; these were called multiple skiagraphs. The experiment proved that more than a single sheet of sensitized paper would be affected by the rays when laid one upon the other, setting aside the theory that the chemical composition of one sensitized film would absorb most of the rays. Owing to the thin sensitized films of the printing paper, very unsatisfactory skiagraphs were obtained. Dr. Kolle now declares that he has overcome these difficulties and that the process of typo-radiography is not a theoretical dream, but is a self-evident and systematic method of procedure. In regard to the practicability of this process, it may be said to overcome first the

cost of labor of composition, secondly, the limited time of striking off copies, and thirdly, the advantage of keeping the entire work a total secret from the printer, a very valuable fact not to be overlooked in diplomatic documents, letters, communications, etc. Dr. Kolle finds a suitable writing ink for this purpose to be composed of red lead, powdered gum arabic, glycerine and water. For type work a semifluid mixture of red lead, potassium bromide, and glycerine sufficient to make a paste would be necessary.

These inks will, however, only permit of white text on a black background unless certain photographic methods are followed, as in the employment of "upset developers," therefore, a second or "unfatty" ink, which will permit of black characters on a white background, must be used. These are made preferably of bichromated mucilage. Bichromated mucilage which has not been exposed to light previous to its use in order that its non-adherent property may be retained, is suggested for the writing. The fatty ink then applied with a roller will adhere to the unwritten portions of the paper, leaving the letters uncovered or free for the penetration of the X-rays. The third method of preparing the phototype is to print or write a text with an adhesive or mucilaginous ink composed of a tacky varnish or gum and then dusting it over with some opaque metallic powder such as mercury biniodide, zinc oxide or lead oxide. The copy would then have to be blown off to render the characters clear cut and the unused space free from mottling opacities resulting from retained dust.

After the copy is prepared, the sensitive paper on which it is to be printed is made into what Dr. Kolle calls a "senso-block," which contains fifty to one hundred sheets. It is then mounted or clamped into a form, the sensitized side upon which the copy or phototype is laid facing up, and it is thus subjected to the action of the X-rays. The current is then turned on for an exposure of ten or twelve seconds, and the block taken to a dark room to be developed. Twenty blocks each containing fifty sheets of paper might be arranged around one X-ray tube to give 1,000 impressions every ten seconds of exposure. This would give about 6,000 copies a minute. Professor Kolle suggests that special gelatino-bromitized films be used and after being photographed to form a block should be made so that it will still retain the features of a single sheet.

The process is extremely interesting, and though it is not regarded as a menace to printing, at the same time there is, unquestionably, a field for the X-ray printing establishment which may only require intelligent development to bring it within the domain of the working arts.

RELATIVE PROPERTIES OF TUNGSTEN AND MOLYBDENUM STEELS.

The production of special qualities in steels by the incorporation in the metal of relatively small quantities of alloying metals, is attracting much attention from metallurgists. It has, in fact, opened an entirely new field of investigation, which gives promise of yielding extremely valuable results.

Apropos to this is the following communication by Mr. R. Helmhacker, in a late issue of the *Engineering and Mining Journal* relative to the peculiarities of tungsten and molybdenum steels, viz.:

"Steel alloyed with a small proportion of tungsten has been used for some years in the manufacture of tools and other articles requiring a hard and tough metal. Some years ago Prof. V. Leepin, of St. Petersburg, Russia, suggested that molybdenum might be used for the same purpose, as it strongly resembles tungsten in its properties. After some discussion he succeeded in having molybdenum steel made at the Pubilov Iron Works, and carried on a number of tests, the results of which were published in the Russian *Mining Journal* for 1897. In making these tests great pains were taken to have the steel, both tungsten and molybdenum, made under the same conditions. Both steels were made in Siemens regenerative furnaces from a charge consisting for the molybdenum steel of 20·6 kilograms of basic open-hearth steel; 2 kilograms Swedish charcoal pig iron; 2·3 kilograms Swedish charcoal blooms; 0·1 kilogram ferro-silicon, and 1 kilogram molybdenum in a metallic form, but combined with a small quantity of carbon. For the tungsten steel the charge consisted of 16 kilograms basic open-hearth steel; 3·7 kilograms Swedish pig iron; 2·9 kilograms Swedish charcoal blooms; 0·1 kilogram ferro-silicon, and 1·8 kilograms ferro-tungsten having 48 per cent. tungsten. Both steels were cast into ingots, which were afterwards rolled into rods of a suitable size for the testing machine. By analysis the percentage of tungsten was found to be 3·8 and that of molybdenum 3·7.

"The experiment showed that the molybdenum steel is somewhat softer than the tungsten steel. Oil tempering and high heating after hardening increased the limit of elasticity in the molybdenum steel. Common tempering in oil has a greater influence on the tungsten steel than on the molybdenum, but on the other hand the molybdenum steel was stronger than the tungsten after heating and hardening in water. Tungsten steel was more apt to split than the other when worked, and broke sooner when bent cold.

"In many respects the properties of the two kinds of steel were very similar, but the molybdenum steel seems to stand forging and hardening better, showing that in some cases it may furnish a better metal than the tungsten steel.

"We have heretofore referred to the use of molybdenum, tungsten and some other of the rarer metals in the processes for making armor-plate at the Krupp works in Germany and the Creusot works in France. At both these establishments the alloys used are kept secret, but it is probable that a mixture of several of the rarer metals is used, including both tungsten and molybdenum."

A DEPARTMENT OF MINERALOGY AND MINING.

Representative Osborne has introduced into Congress a bill providing for the establishment of an executive Department of Mineralogy and Mining. These subjects in the United States are of such great importance, that there should certainly seem to be a legitimate field for the creation of another department.

"That there shall be established at the seat of government an executive department, to be known as the Department of Mineralogy and Mining, the

objects of which shall be to gather and diffuse among the people of the United States practical and useful information pertaining to mining in all its branches. Said department shall be under the supervision and control of an executive officer, to be known as the Secretary of Mineralogy and Mining. Said officer shall be appointed by the President, by and with the advice and consent of the Senate. There shall be an Assistant Secretary of Mineralogy and Mining. The Secretary of Mineralogy and Mining shall receive the same salary as is paid to the Secretaries of the executive departments of the government. The Geological Survey, as at present established, together with all records, maps and apparatus now connected therewith, shall be transferred to and made a part of the contemplated new department. This act shall go into effect and be in force on the fourth day of March next succeeding the day of its final passage."

RESISTANCES FOR ABSORBING LARGE POWERS.

A contributor to *L'Electricien* describes an ingenious construction of rheostat for absorbing an output of 400 kilowatts used in testing the generators in the station at Nancy, France. The rheostat consists of galvanized iron netting ordinarily used in protecting the underground distribution cables, the particular advantage obtained in using this material apparently being the enormous radiating surface per unit cross-section. A strip of this netting about 11 inches wide, composed of sixteen strands of galvanized iron wire with a cross-section of about $\frac{1}{160}$ of a square inch, the whole strip being 180 feet long, absorbs 500 ampères at 240 volts, the strands remaining at a temperature below that of the fusing point of lead.

Franklin Institute.

(Proceedings of the Stated Meeting held Wednesday, November 15, 1899.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 15, 1899.

MR. JOHN BIRKINBINE, President, in the chair.

The chair was taken at 8 o'clock, P.M.

Present, 109 members and visitors.

Additions to membership since last report, 32.

Letters of acknowledgment of election were presented from the following: Rear-Admiral G. W. Melville, U. S. N., Mr. Ralph W. Pope, Dr. Coleman Sellers, Dr. Robert H. Thurston, Dr. Charles F. Himes, Dr. Harvey W. Wiley, Prof. Martin H. Boyé, Dr. T. C. Mendenhall, Hon. Frederick Fraley (honorary members) and Mr. T. Commerford Martin (corresponding member).

A circular of "Directions for Amateur Meteor Photography," issued by the Physical and Astronomical Section for the information of members of the Institute who may desire to make photographic records of the meteoric showers expected to occur about this time, was presented for distribution.

The papers of the evening were then announced.

Capt. E. B. Babbitt, U. S. A., presented a communication on "Recent Developments in Military Powders and Explosives in the United States." The speaker illustrated the subject with the aid of specimens of high explosives now in use in the United States army, and by a series of lantern slides. (Referred for publication.)

MR. A. E. OUTERBRIDGE, JR., in the chair.

Mr. T. D. Mullan presented a communication on "Rubber Substitutes and their Applications to the Arts, with Especial Reference to the Products of the Manufactured Rubber Company." The subject was illustrated by the exhibition of an interesting collection of specimens, exhibiting the new products in all stages of manufacture. Mr. Mullan's paper will appear in the *Journal*. Referred to the Committee on Science and the Arts.

Mr. W. N. Jennings presented a communication of Prof. R. W. Wood, of the University of Wisconsin, on "The Causes of Dark Lightning and the Claydon Effect," illustrated with a number of lantern slides. An abstract of the communication will appear.

The chair expressed the thanks of the meeting to the speakers.

Adjourned.

WM. H. WAHL, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of the proceedings of the stated meeting held Wednesday, November 1, 1899.*]

PROF. EDGAR MARBURG in the chair.

The following reports were adopted:

Acetylene Gas Generator.—John Condon, Philadelphia.

ABSTRACT.—This machine belongs to the class known as "drop machines," in which the calcium carbide is fed gradually to relatively large quantities of water. This type of machine the Committee considers to be superior in principle to the other two recognized types, *i. e.*, those in which water is added from time to time to large quantities of the carbide; and those in which the carbide is contained in wire baskets and the level of the water rising to or receding from it, is regulated by the pressure of the acetylene gas.

In the Condon machine the feeding of the carbide to the water is made automatic by actuating the feed mechanism by means of the rise and fall of the gasometer. The machine also embodies special devices to ensure safety in charging to prevent the escape of gas.

The Investigating Committee finds that the problem of automatically feeding carbide to water for the purpose of generating acetylene gas has been solved in this apparatus in a satisfactory manner, and that the apparatus is of good construction, well designed and safe in use.

The device is protected by letters-patent of the United States, No. 617,563, January 10, 1899, and No. 627,885, May 13, 1899, granted and assigned respectively to applicant. [*Sub-Committee.*—Chas. A. Hexamer, Chairman; Harry F. Keller, Wm. McDevitt.]

Pocket Recorder for Tests of Materials.—Gus. C. Henning, New York.

ABSTRACT.—The object of this device is to furnish at a reasonable cost a portable autographic recorder, which may be applied to any testing machine which has a running poise weight without causing delay for adjustment, the results being at the same time reliable and such that they can be at once interpreted.

The apparatus consists essentially of three parts: The top and bottom clamps which secure it to the test piece; the parallel-motion mechanism, similar to that employed on a steam-engine indicator, with a pencil at the extremity of the long lever moving at a rate proportional or equal to the stretch or compression of the test piece; and the drum or frame, carrying a sheet of paper on which the record is made, and which moves at a rate proportional to the stress to which the test piece is subjected.

The record is thus a continuous and complete graphical representation of the condition of stress and strain at any and all points between the initial application of stress and the rupture of the test piece.

The investigators find the apparatus to possess the following points of merit: Portability, compactness, the method of gripping specimen, the magnification of the strain in the stress-strain diagram up to the yield point and the normal record from this point on to rupture. The report concludes as follows:

"While not possessing any strikingly new features, the instrument cleverly condenses and combines the strong points of existing appliances, and makes a recorder readily adaptable to any except hydraulic machines." A certificate of merit is awarded. [*Sub-Committee.*—Wilfred Lewis, Chairman; Tinius Olsen, Richd. L. Humphrey.]

Electric Car-Lighting.—Morris Morris Moskowitz, Newark, N. J.

ABSTRACT.—The Moskowitz system belongs to the type of car-lighting systems in which a dynamo-electric machine driven directly from the car axle keeps a set of storage batteries charged, so that each car, when in service, is always in condition to supply its own lights.

[The report is reserved for publication in full.] The John Scott Legacy Premium and Medal is recommended. [*Sub-Committee.*—Arthur J. Rowland, Chairman; R. A. Scott, Chas. J. Read, Geo. F. Stradling.]

Book and Letter Typewriter.—R. J. Fisher.

ABSTRACT.—The apparatus investigated is an improved typewriting machine designed for printing characters on the pages of blank-books, or on loose sheets of paper, by means of steel type and an inked ribbon. [Reserved for publication in full.] The John Scott Premium and Medal is recommended. [*Sub-Committee.*—J. Logan Fitts, Chairman; H. R. Heyl, Samuel Sartain, Hugo Bilgram, Edward F. Moody.]

Static Machine X-Ray Apparatus.—Sweet & Lewis, Boston, Mass.

ABSTRACT.—This consists of a Holtz machine outfit specially designed for the convenient production of X-ray phenomena. The original part of the combination the investigators find to consist in the commutating device, which is made to serve the double purpose of reversing the discharges and of adjusting their frequency and magnitude.

The report concludes that the apparatus is portable, seems reliable and efficient, and in respect of the commutating device is original. A certificate of merit is awarded to the manufacturers. [*Sub-Committee.*—A. E. Kennelly, Chairman; Geo. F. Stradling.]

Portable Photometer.—Charles Deshler and Edwin J. McAllister, Newark, N. J.

This apparatus was described in the *Journal* for November, 1899. (*See* article "Photometry of Incandescent Lamps," Rowland, p. 376.)

The investigators find that the apparatus is well adapted for the purposes of its design. A certificate of merit is awarded. [*Sub-Committee.*—Arthur J. Rowland, Chairman; Francis Head, F. E. Ives.]

Piston-Valve for Steam Engines.—J. H. Dunbar, Youngstown, O.

Steam Turbine.—Samuel Colt, Santa Barbara, Cal.

Brake Mechanism for Railway Cars.—Harper M. Smith, Philadelphia.

Window-sash Slide for Railway Cars and Vessels.—W. Curtis Taylor, Philadelphia.

Electric Motor.—Arthur H. Beard, Philadelphia.

(In these cases the reports were advisory.)

The following passed first reading:

Drawing-Tables.—Samuel J. Loughlin and James Hough.

SECTIONS.

[*Abstract of Proceedings.*]

COMMEMORATIVE MEETINGS, October 2 to October 6, 1899.

The program for the celebration of the Seventy-fifth Anniversary of the Franklin Institute embraced a series of Commemorative Meetings. These were duly announced, and were held in Convention Hall of the National Export Exposition, beginning Monday evening, October 2d, and continuing on successive evenings of the week until Friday evening, October 6th.

The Commemorative Meetings were held in the following order:

CHEMICAL SECTION.—Monday, October 2d, Dr. Jos. W. Richards in the chair.

Mr. John Birkinbine, President of the Institute, made a brief address, apropos to the occasion, in which he sketched the progress of the Institute, and dwelt upon the steady expansion of its work.

Dr. Richards made the introductory address, and presented Dr. Harvey W. Wiley, Chief Chemist to the U. S. Department of Agriculture, who also made an address on "The Relation of Chemistry to the Advancement of the Arts."

Dr. Chas. F. Himes, of Carlisle, Pa., followed on behalf of the Photographic and Microscopic Branch with an address on "The Making of Photography."

(The addresses appear in the *Journal.*)

ELECTRICAL SECTION.—Tuesday, October 3d, Prof. George A. Hoadley in the chair.

The President of the Section introduced Prof. Edwin J. Houston, who delivered an address on "The Seventy-fifth Anniversary of the Franklin Institute from an Electrical Standpoint."

Mr. Ralph W. Pope, Secretary of the American Institute of Electrical Engineers, followed with an address on "The Influence of Technical Societies in Promoting the Progress of the Arts."

(The addresses appear in the *Journal.*)

MINING AND METALLURGICAL SECTION.—Wednesday, October 4th, Mr. James Christie in the chair.

In a brief introductory address, referring to the objects sought to be accomplished by the Section, the Chairman introduced Mr. John Fritz, of Bethlehem, Pa., who addressed the meeting on "The Development of the Iron Manufacture in the United States."

Mr. Chas. Kirchhoff, editor of the *Iron Age*, followed with an address entitled "Three-quarters of a Century's Progress in Mining and Metallurgy."

(The addresses appear in the *Journal.*)

MECHANICAL AND ENGINEERING SECTION.—Thursday, October 5th, Mr. Wilfred Lewis in the chair.

The Chairman made an opening address, dwelling on the operations of the Section and its opportunities for usefulness, and introduced the speaker of the evening, Dr. Coleman Sellers.

Dr. Sellers made an address on "The Progress of the Mechanical Arts in the Past Three-quarters of a Century."

(Presently to appear in full in the *Journal.*)

PHYSICAL AND ASTRONOMICAL SECTION.—Friday, October 6th, Dr. A. E. Kennelly in the chair.

Dr. Kennelly delivered an introductory address, and was followed by Dr. T. C. Mendenhall, President of the Worcester Polytechnic Institute, who spoke on "The Progress of Physics and Astronomy."

(To appear in full in the *Journal.*"

CHEMICAL SECTION.—*Stated Meeting*, Tuesday, November 21st, Dr. Williams, Vice-President, in the chair.

Present, 34 members and visitors.

Dr. Francis Wyatt, of New York, member of the Section, delivered a lecture on "The Influence of Science in Modern Beer Brewing," a carefully prepared and masterly presentation of the subject. Discussed by Dr. H. F. Keller, Dr. Williams and the author. The paper is referred for publication. The meeting tendered a vote of thanks to the lecturer and adjourned.

PHOTOGRAPHIC AND MICROSCOPIC BRANCH.—*Stated Meeting*, Tuesday, November 7th, Dr. Henry Leffmann, President, in the chair.

Present, 44 members and visitors.

Mr. Frank V. Chambers, editor of *The Commerce*, gave an exhibition with the aid of the lantern, of pictures made by the McDonough process of color photography, and gave some explanation of the method.

The subject was discussed by Messrs. J. F. Sachse, L. E. Levy, Fred. E. Ives and Chambers. Mr. Ives gave a brief sketch of the history of this system of producing color effects in photography.

The principal paper of the evening was contributed by Dr. Chas. F. Himes, of Carlisle, Pa., member of the Section, who addressed the meeting on the subject of "Photographic Record Work." Dr. Himes advocated, as part of the systematic work of the Branch, the formation of a collection of photographs preservative of interesting facts—scientific, historical, etc.—otherwise liable to be lost, and the proper arrangement of such a collection for preservation and reference.

The value of photographic work of this kind was illustrated by reference to similar work carried on elsewhere, and was exemplified by the exhibition of photographic reproductions of historically valuable scientific apparatus, ancient MSS., newspapers, etc., contributed by Mr. Sachse, Dr. Leffmann and Dr. Himes. The subject was freely discussed by the members just named, Mr. W. N. Jennings and L. E. Levy. The President announced that the work of preparing a plan for the proper undertaking of such work by the Branch had been confided to a special committee, to report at a subsequent meeting.

ELECTRICAL SECTION.—*Stated Meeting*, Tuesday, November 28th, Prof. Wilbur M. Stine in the chair.

The principal paper of the evening was read by Mr. F. W. Willcox, of the General Electric Company, Harrison (Newark), N. J. Subject: "Incandescent Lamps," and was well illustrated by means of specimens, charts and lantern slides.

Mr. W. E. Harrington followed with a communication on "Rail-bonding," giving the results of practical experience in the use of various methods and conclusions as to the most approved types of such devices.

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, Wednesday, November 8th, President James Christie in the chair.

Mr. Charles James, member of the Section, presented a communication on "The Annealing of White Cast Iron," which embodied the results of much practical experience in this branch of foundry work. A discussion followed on the general subject of iron and steel castings.

MECHANICAL AND ENGINEERING SECTION.—*Stated Meeting*, Thursday, November 9th, Mr. Wilfred Lewis, President, in the chair.

Mr. Henrik V. Loss, member of the Section, read the first installment of a paper on the "Pressing of Steel," treating specially of the flow of steel. Discussed by Mr. James Christie, the President and the author. Referred for publication.

PHYSICAL AND ASTRONOMICAL SECTION.—*Stated Meeting*, Friday, November 10th, Dr. A. E. Kennelly, President, in the chair.

The following communications from the Section's collaborators were presented:

"A brief Report of some late Determinations of the Density of the Earth," by Prof. A. Stanley Mackenzie.

"The Daguerreotype," by Prof. E. A. Partridge.

"A short History and Discussion of the Florentine Enigma," by Prof. C. B. M. Zerr.

A general discussion of the topics followed.